CPE Comments and Topics

The chemical future

THE 1950s were the fat years for Europe. Having barely survived the most monstrous war in the history of mankind, Europe rebuilt her shattered industry and prospered as never before. Many indeed felt that this boom was permanent—things would just get better and better. Economists warned at the time that this was an illusion and they were to some extent vindicated at the outset of the American recession in 1958. Since then there have been several crises in British industries, notably shipbuilding, aviation and the consumer products industries like motor-cars. Strangely enough, however, the chemical industry has emerged practically unscathed from this recession, which in itself is sufficient evidence of its fundamental soundness.

According to the O.E.E.C. review 'The Chemical Industry in Europe, 1959-60' just published, the increase in production for Europe's chemical industry in 1959 exceeded that of 1958 by 13%—compared with a modest 5% for all manufacturing industries. To what can this continuing, unabated chemical prosperity be attributed? Clearly not to the foresight of economic planners, because chemical prosperity has occurred in countries whose economic and political structures vary in the extreme.

One cannot rule out a simple, straightforward explanation for this phenomenon: that the underlying cause is due to the expansion of traditional materials and the need for entirely new products. Thus consumption of fertilisers, soaps and detergents increases mainly as a consequence of the general standard of living. On the other hand, a plastic material may be developed to fill the need for an entirely new material of construction (reinforced plastics is a good example) which can compete with traditional materials such as glass, timber or steel and to some extent replace them.

Substitution therefore plays an important role; a new pharmaceutical product may well replace the more traditional drugs.

Another factor not always clearly appreciated is that the chemical industry is a heterogeneous complex made up of two dissimilar sections, the manufacture of plant on the one hand and the manufacture of chemicals on the other. The former is naturally dependent on the good health of the latter, but is still a separate entity, being a little more flexible because of the rationalisation of chemical plant construction. It would seem, therefore, that the chemical plant industry is in a slightly better position to weather an economic crisis that might affect one particular sector of the chemical manufacturing industry.

The O.E.E.C. report states that the price structure for chemical materials was quite stable during 1959—in fact, prices fluctuated less than the prices of commodities in general. Total investment in the chemical industry of nine of Europe's most populated countries amounted to about $1,190 million in 1959, compared with $1,230 million for the same period in the U.S. This represents 17% of total chemical investments for Europe and 9% for the U.S. or $920 per person employed in the European chemical industry compared with $1,450 per person in the American chemical industry (reflecting, possibly, the greater degree of automation in the U.S.).

Although the total capital invested in chemical plant now in operation in both Europe and the U.S. is not known, it is obvious that the U.S. has accumulated more capital in its chemical industry than Europe has, mainly because chemical prosperity dates back more than 20 years ago in the U.S. None the less, Europe is already well on its way towards catching up the American lead.

Despite these optimistic signs the report warns that the steady increase in labour costs must be closely watched. We can only maintain our increasing productive capacity and steady price level by expanding exports at a far more drastic rate than hitherto. The percentage of total chemical products exported range from 9% for Italy, 17% France, 19% U.K., 22% Sweden, 25% Germany, 38% Denmark, 53% the Benelux countries and 80% Switzerland. It is obvious from these figures that only the smaller countries in Europe are succeeding in their export drive. They have learned from bitter experience that without exports they cannot survive. Is it not high time that the chemical industry in this country learned the same lesson and devoted more energy to the 'tough' export markets—instead of relying on the 'safe' markets in the Commonwealth? Unless this is done soon Britain's chemical future will look far less rosy at the end of this decade than at present.

Department of lost causes

ONE of the Englishman's most baffling yet endearing traits is his espousal of lost causes. Support for lost causes comes mainly from well-meaning but woolly-thinking politicians who would be doomed to perpetual oblivion were they not to seek the limelight *via* the creation of lost causes. Generally, these causes are intrinsically harmless and we can afford to adopt a tolerant attitude towards them. But when they threaten to impede the tempo of efficient industrial progress it becomes a different matter altogether.

The rumpus recently caused by the supposed menace of pipelines is a good example of the inherent harm that can be created by the 'department of lost causes'. Suddenly these watchdogs of public

interest have discovered that pipelines are spreading across England's green countryside and legislation has been suggested to curb this supposed evil. Now, to any clear-thinking person it would seem obvious that at a time when road and rail transport are unable to cope with existing traffic that essential products like fuel oil and gas can best be transported from the refineries to the cities by an extensive network of cheap and efficient pipelines. This point is hardly appreciated by the 'lost causers' and, as a result, legislation will soon impede progress in this form of transportation.

What are other countries doing with pipelines? In continental Western Europe an extensive network of pipelines is being planned to link the ports with industrial inland centres (see CPE, 1960, **41,** 275). An even more ambitious programme planned will be the laying of two pipelines, one of which will join the Soviet Union to Hungary and Czechoslovakia and the other will pass from the Soviet Union to Plock in Poland where an oil refinery will be erected. This pipeline will continue to Schwed in East Germany where a 56-million-bbl.-p.a. refinery will be built. This pipeline is scheduled to be completed in 1963. Are we in this country even contemplating such a network?

Modern developments in pipelining and rationalising of pipelines are surveyed in this month's special feature on pipelines. Our readers can gain some insight into this relatively new technology which will become increasingly important during the coming years.

Corrosion in nuclear plant

THE International Congress of Metallic Corrosion which took place in London during the first weeks of April brought together scientists and technologists from all parts of industry. It served as a most useful forum for mutual exchange of basic knowledge on corrosion. The corrosion behaviour of constructional materials in nuclear plant was surveyed by W. T. Edwards at this congress in a paper, 'Aqueous Corrosion in the Atomic Energy Industry'. The author considered the difficulties encountered when using nitric acid for the dissolution of nuclear fuels and the processing of slags, and of hydrofluoric acid for production of uranium tetrafluoride.

Nitric acid has been extensively used as a solvent for nuclear and irradiated fuels and, because the intense radioactivity involved in processing most nuclear fuels precludes maintenance and renewals during an operational cycle, any material chosen must be of the highest integrity, especially in the welded condition. A review of available stainless steels has led to the adoption and development of the 18-13-1 Cr-Ni-Nb austenitic steel as most suitable for highly active conditions. The presence of niobium as a stabiliser reduces the tendency for carbide precipitation and knife edge weld attack. Laboratory tests have, in fact, shown that the corrosion rate of this steel is significantly less than that of 18-8-Ti steel.

In processes involving the use of fluoride and nitric acid Edwards suggests that stainless steel is not a suitable constructional material under boiling or near-boiling conditions. Of alternative alloys investigated, tantalum, titanium and the nickel-based 65-35 Ni-Cr alloy show most promise, although they are not entirely satisfactory and are restricted to low fluoride concentrations and temperatures below boiling.

For plants using hydrofluoric acid, *Monel* is the most convenient constructional material and is satisfactory provided oxygen levels can be maintained at low values in the blanket gas. *Monel* is not particularly susceptible to stress corrosion although, under some circumstances, it is possible that cases of suspected stress corrosion have occurred and all components should be stress relieved where possible.

It is inevitable, as Edwards has shown, that a large part of the capital cost in the nuclear industry is expended on the special-purpose alloys to resist both the radioactive contamination and corrosion which occurs during processing. This is probably one of the main reasons why this industry requires so much capital, yet one often wonders whether sufficient work is carried out in examining the suitability of some of the cheaper plastics and non-metallic materials for use in nuclear plant.

Reduced porosity graphite

PROCESSES for reducing the natural porosity of graphite have been recently developed by the Hawker Siddeley Nuclear Power Co. The normal commercial processes for producing graphite result in a material which is able to withstand high temperatures and to resist the action of corrosive gases and fluids. The nature of the chemical changes during production make graphite very porous to both gases and fluids and this imposes certain limitations to its application in the engineering field and in consumer goods.

Development of graphite originated with a requirement to produce improved types of graphite for use as fuel-element cans in high-temperature, gas-cooled reactor systems. This type of reactor is being designed to operate with a core temperature in the range 600° to 1,000°C., thus offering the possibility of considerable economies in operation compared with the original Calder-type reactors. Reactors of this type are at present being designed and built at Winfrith (the O.E.E.C. DRAGON project), by the Brown Boveri-Degussa-Krupp Consortium in Germany (Pebble-bed reactor) and by the General Atomic Division of General Dynamics Corporation in the United States.

The work started by using the furfuryl-alcohol process, first developed successfully by the Royal Aircraft Establishment, and subsequently sponsored by the A.E.R.E. at Harwell. A number of other new processes designed specifically to meet the needs of a wide range of grades of graphite were subsequently introduced. The applications for this include impregnated graphite bursting discs, special grades for high-temperature bearings and bushes, corrosion-resistant grades for use in chemical plant and heat exchangers and oxidation-resistant graphites for use in oxidising atmospheres.

Modern trends in crystallisation

CRYSTALLISATION as a unit operation has advanced spectacularly during the past 50 years from an empirical art to almost a fundamental science. Much of the credit for this progress is due to physical chemists who have consistently investigated the mechanism of crystal formation and the relationship between initial nucleation and final crystal structure. Apart from this, more classical chemical engineering concepts such as heat and mass transfer have been applied with much success to the design of crystallisers.

H. B. Caldwell in the February 1961 issue of *Industrial and Engineering Chemistry* defined three concepts that distinguish the modern crystalliser from its predecessors. These are: removal of excess nuclei or fines, circulation of the growing crystals to the zone where supersaturation is being produced and maintenance of high magma density in circulation. These factors were considered by the author in relation to a continuous crystalliser that produces supersaturation by vacuum cooling rather than by evaporation.

This vacuum crystalliser is of the draft tube and baffle type with a propeller that causes upward flow in the draft tube; the fines removal area is between the cylindrical baffle and the shell. If there is no flow through this annular space because of the fines removal stream, only clear liquor is present. However, when the fines removal stream is in operation a definite upward liquor velocity is established. In this way excessive nuclei or fines can be removed from the crystalliser; in addition the rate of flow of the fines removal stream controls the magma density in the crystalliser.

Apart from the above-mentioned three concepts, the author also suggested that 'togetherness' or propinquity of the crystals is important, especially since supersaturation in a crystalliser is rather a fleeting phenomenon and new nuclei will be formed if the supersaturation has to travel far before reaching a crystal on which it may deposit as growth.

This particular crystalliser can produce 16 to 20-mesh crystals of sound structure and high uniformity from a number of common chemical solutions such as potassium chloride, borax and ammonium bisulphite. If extreme uniformity is required an elutriation leg discharge arrangement may be used. This permits crystals smaller than those desired to be retained in the crystalliser for an additional length of time.

Despite all the many recording and control instruments with which the crystalliser is equipped, it is still necessary to keep handwritten logs and personal control over its performance. Caldwell rightly stresses the importance of peering intently into a peephole to observe the character of the circulation, its pattern, its degree of turbulence, the froth and foam and the spatter of crystals on the sight glass. Inevitably, much of the behaviour of crystallisers is not yet amenable to rational explanation—there is therefore no substitute for intelligent observation.

Natural gas in Holland

THE discovery of substantial natural gas deposits in Holland's northern province of Groningen may completely alter the fuel structure of Europe. Reports of this discovery were first published in *The Economist* several weeks ago, but Dutch government officials have been reluctant to reveal the estimated quantity of reserves in this deposit—a conservative estimate is thought to be 60 milliard cu. m.

Apparently this new gas deposit was discovered in 1960 by an oil prospecting company, N.A.M., which is jointly owned by Royal Dutch Shell and Standard Oil of New Jersey. The deposit has been sealed up until a decision is made whether to proceed with commercial exploitation of the gas—this requires huge investments in transport, marketing and storage systems. In order to arrive at a decision, N.A.M. must take into account present production of gas at Dutch refineries as well as the projected plan for importing liquefied methane from North Africa. Britain may also be tempted to preferentially import liquefied gas from Holland rather than from the Sahara, since the capacity of Dutch gas reserves should be sufficient to cover a large part of home consumption and allow for some export.

One indication of the importance that Dutch authorities are attaching to these deposits is that Staasmijnen (the Dutch State Mines) have planned to erect a petrochemical plant near the gasfields in order to convert the gas into nitrogenous fertilisers and plastics. This may well prove a challenge to north-west Europe's fuel and petrochemical industry.

Rumania's chemical industry

RUMANIA has traditionally served as Central Europe's grain belt. Although she has vast resources of oil and other minerals, industrialisation was never considered as a serious proposition until after the second world war. Since then rapid strides have been made in creating the nucleus of an industry that will be based to a large extent on available natural raw materials.

Thus the production of oil, natural gas, iron, manganese, copper, chrome, bauxite and salt has increased almost tenfold since 1938.

More stress is currently placed on natural gas, especially as a raw material for a petrochemical industry. Rumanian gas has a very high methane content ($>99.5\%$) and various chemical plants, already in existence since 1958, can process this gas to obtain methanol, formaldehyde, acetic acid and anhydride. Rumanian gasoline has a very high naphthene content and processes have been designed using this gasoline to crack cyclohexane and isomerise methylcyclopentane in order to obtain caprolactam. A plant is at present planned to obtain aromatic hydrocarbons like benzene, toluene and xylene by catalytic conversion from refined gasoline.

There has also been considerable activity in the inorganic chemical industry. Sulphuric acid is made

in four different plants and two new soda plants recently came on-stream. There are, in addition, two chlorine-alkali electrolytic plants and a third is being planned. Rumania expects to become self-sufficient in fertiliser production within the next five years. At present there is one fertiliser plant in Fagaras with a capacity of 100,000 tons p.a. By the end of 1960 a scheduled plant in Roznow should be on-stream with a potential capacity of 350,000 tons p.a. nitrogenous fertiliser.

Apart from these basic chemical industries, there is considerable activity in the plastics, synthetic fibres, pharmaceutical and paper industries. Although these are all at present rather small, considerable expansion plans have been proposed for them. It is expected that by 1965 the balance will be shifted from agriculture to industry and that Rumania, with a small population of 18 million, will become one of Europe's highly industrialised countries.

Re-thinking coal

'THE world does not owe the coal industry a living; it must make its own way against the tremendous competitive ability of the vast international oil organisations'. This was stated by Mr. Alfred Robens chairman of the National Coal Board at the recent annual dinner of the Institution of Plant Engineers. Mr. Robens continued by giving interesting factual details. The coal industry is still the greatest single industry in Britain—employing more people than are serving in the armed forces. Many changes are now taking place in this industry—in three years the sales of coal had been reduced by 33 million tons—nevertheless, there will be no more contractions based on the closure of pits for economic reasons. During this year the Coal Board is launching the biggest mechanisation drive in the history of the mining industry, its aim being to increase the percentage of 'power-loaded' coal produced to 80%.

Mr. Robens pointed out that by 1965, 80% of the coal produced from British mines would be from pits that were either brand new or had been completely reconstructed. These are very wise and realistic policies. We have often pointed out in these columns that the old-fashioned view taken by some planners that because coal is Britain's only large-scale indigenous fuel it must *ipso facto* receive priority treatment no matter how high its costs, is utterly ridiculous.

Increase in coal production efficiency followed by decrease in coal costs must be the prime consideration, if coal is not to lose further ground to oil. In this context the decision to concentrate on blending coal is most reasonable. Perhaps further considerations might be the possibility of combining different fuels; one example (now studied by the Gas Council) is the blending of coal gas with liquefied petroleum gases to make a reformed town gas. Other examples are the design of boilers to burn very low-rank coal (*e.g.* high-ash anthracite) together with fuel oil. Only by taking such a broad view can the consumer ever benefit from the multitude of fuels at his disposal.

Shortage of phthalic anhydride

SATISFACTORY progress during the last year was reported by Monsanto Chemicals chairman, Sir Miles Thomas, in his annual statement for 1960. The company, which produces a variety of inorganic chemicals as well as many types of plastics and synthetic rubbers, had a record turnover of more than £20 million of which 35% were direct exports. Due to the government credit restrictions which were imposed in 1960, there was some reduction in sales of certain plastics, for instance polystyrene for consumer items such as refrigerators and radio and television cabinets.

The statement added that, due to the general shortage of naphthalene as a raw material for phthalic anhydride there was some curtailment in phthalic anhydride production. It is, however, expected that this position will improve during 1961 and that all demands for phthalic anhydride will be satisfied during this year. There is a similar shortage of maleic anhydride which should be remedied as soon as a new plant commissioned recently is completed.

It is interesting to note in this context that a new process has been designed by the Scientific Design Co. by which phthalic anhydride can be obtained from ortho-xylene in yields comparable to those obtained from naphthalene, *i.e.* of the order of 85 to 90 lb. phthalic anhydride per 100 lb. ortho-xylene. In addition, appreciable quantities of maleic anhydride are produced by ortho-xylene oxidation and these can be inexpensively converted to fumaric acid. It is therefore felt in many circles that a major shift will develop from naphthalene to ortho-xylene as producers re-evaluate the economics of this process.

Secretarial efficiency

AT last a law has been formulated to determine accurately the scientific productivity of a research laboratory. The law is expressed by:

$$P = \frac{S \times ATS}{Sc}$$

where P = productivity, Sc = number of scientists, ATS = average typing speed and S = number of secretaries.

Robert Sommer, the author of this law, is a psychologist working at the Saskatchewan Hospital, Canada. He first published it in the *Worm Runner's Digest*, the journal of the Department of Psychology, University of Michigan.

Sommer notes that a characteristic of this equation is that when the number of scientists becomes zero productivity becomes infinite! This is quite true of course—although few of us would be brave enough to admit it. Just how much secretaries have contributed to scientific progress remains one of the great unsolved mysteries. We call to mind, for example, the physicist, who in the early days of atomic energy dictated a lengthy erudite report entitled 'nuclear theory'. Finally it arrived on his desk beautifully typed, but retitled 'unclear theory'. Who made the mistake?

Pipelines in the Oil Industry

Pipelines from the British Petroleum Co. refinery at Aden to the oil harbour

By J. D. Graham
B.Sc., A.R.T.C., A.F.Inst.Pet.

A pipeline is a method of transportation as distinct from pipes which are connecting media, and is an alternative to transportation by road, rail or sea. Little has been published in Britain concerning the economics of oil pipeline construction and operation. These aspects are discussed by the author, special reference being made to the operation of multi-products pipelines.

THE physics of the conveyance of fluids by pipeline do not differ in any way from normal calculations for pipes in general excepting in degree, that is, the various factors for the given fluid and type of tubes are multiplied in the case of a pipeline by 50 or 100 miles instead of by 100 or 1,000 ft. Design calculations for fluid flow have been studied and published exhaustively, and it would be merely tedious to repeat them here. It is intended, therefore, to concentrate upon the economic aspect of the construction and operation of pipelines on which less has been published in this country, and on unique features of the operation of a multi-products white-oil pipeline.

Advantages and disadvantages

The following points require to be borne in mind when considering the pipeline as a means of transportation.

The laying of a pipeline involves considerable interference with the private individual along the route, both before and during construction. The rights of the private individual are upset in a manner comparable only with the construction of the canals and the railway system. This is a characteristic which it shares with one other modern development — the motorway. Justified or unjustified adverse publicity can hurt sales.

Once laid, the pipeline is out of sight for good. In peace time it is virtually invulnerable and in time of war of considerable strategic value. However, once it has been laid it is fixed, and if the pattern of demand should change this means of transportation cannot be switched. The pipeline and its operation are quite unaffected by weather.

The manpower required per ton mile is extremely low, only a few per cent. of manpower required for any other means of transportation. The pipeline has a very long life, certainly more than half a century if properly installed and maintained, and a low maintenance cost. However, if it does fail, no temporary measure is likely to be able to cope with the demand satisfied by the pipeline. There is, in fact, no immediate replacement, but as a rule, repairs can be made in a few days.

For large volumes the pipeline is a very rapid means of transportation, roughly one day per 100 miles. On average any other means of transportation would require four days. A disadvantage of the pipeline is that it is of limited capacity. Once laid, it is quite inflexible, therefore the investment will be for longer term than in the case of an alternative means of transportation. It is usual to design a pipeline for the demand anticipated 10 or 15 years ahead.

Up to 80% increase in throughput can be achieved by installing intermediate pumping facilities, but the pipeline itself, of course, is unalterable. A pipeline is as versatile as other means of transportation in the variety of products that can be handled.

Economics

It is impossible, for a number of reasons, to generalise on comparative costs of transportation by pipeline, road, rail and sea. It is easy to work out a cost per ton mile for a given

rate of delivery of a given product by the four alternative means. Unfortunately, however, comparison is impossible as the four routes differ in length, in some cases by a ratio of 4 : 1, as a glance at a map will make clear. For example, it is about 80 miles as the crow flies from Southampton to London, and about 270 miles by sea. The road and rail routes involve two further different mileages. Total cost for the transportation of a particular quantity between the same two points is the only valid and valuable comparison. Four cases can be compared then for this specific project, that is Southampton to London, but the study is valueless for any other two points in the country of the same distance apart.

Every transportation problem requires separate examination. For this reason it has been thought unsound to do more than set out the economics for the two sizes of a pipeline assuming a distance of 100 miles, which is about the length of a pipeline likely to be built as a unit in this country (see Table 1 and Fig. 1). Again a glance at a map will make clear the reason for this statement if distances between ports and industrial centres are looked at.

With regard to Fig. 1, it should be mentioned that interest has not been included in setting up the curves. Thus, depending on the interest rate, the break-even point is that point at which it becomes worth considering going to a 10-in. in place of an 8-in. pipeline. The higher the interest rate the further to the right would be the actual point at which a change to 10-in. would be made.

Table 1 is self-explanatory and is set out so as to form a useful basic pattern for a pipeline economic study. Certain broad figures stand out, and may be of value, such as £10,000/mile for 8-in. pipe completely installed.

Table 1. One-hundred-mile pipeline

Line size:		
Nominal diameter	8 in.	10 in.
Outside diameter	8⅝	10¾
Inside diameter	7.981	10.02
Capacity:		
Barrels per mile	327	515
Imperial gallons per mile	11,400	18,000
Capital:	£	£
Pipeline cost per mile	10,000	12,000
Pump station cost per b.h.p. installed	150	150
Construction cost breakdown:		
Easement and reinstatement	9%	8%
Materials	43%	45%
Construction	48%	47%
Capital required:	£	£
Pump station (650 b.h.p.)	100,000	(1,200 b.h.p.) 180,000
Pipeline	1,000,000	1,200,000
Totals	1,100,000	1,380,000
Throughputs with one pump station and maximum pressure of 1,200 p.s.i. (bbl./day):		
From	10,000	20,000
Up to	22,000	40,000
Operating costs per annum:	*8 in.*	*10 in.*
(*a*) *Fixed:*	£	£
Personnel at pump station	15,000	15,000
Personnel on line maintenance	5,000	5,000
Communications	2,000	2,000
Line maintenance, £35/mile	3,500	3,500
Cathodic protection energy	1,000	1,000
Rates and taxes (about 2½% capital)	25,000	30,000
Sub-totals	51,500 (4.7%)	56,500 (4.1%)
Depreciation at 3.33%	37,000 (3.3%)	46,000 (3.3%)
Total fixed costs	88,500 (8.0%)	102,500 (7.4%)

(Figures in brackets denote percentage of capital)

(*b*) *Variable:* Electricity (1.25d./unit)	*8 in.*			*10 in.*		
Throughputs, bbl./day	12,500	18,000	22,000	22,000	32,000	40,000
Annual cost, £	5,000	14,700	27,000	9,000	26,000	49,000
Summary of operating costs (pence/bbl.):						
Throughputs, bbl./day	12,500	18,000	22,000	22,000	32,000	40,000
Pumping pressure, p.s.i.	400	800	1,200	400	800	1,200
Fixed costs, pence/bbl.	4.66	3.24	2.64	3.00	2.10	1.68
Variable cost, pence/bbl.	0.27	0.54	0.81	0.27	0.54	0.81
Total cost, pence/bbl.	4.93	3.78	3.45	3.27	2.64	2.49

It is difficult to find an industrial centre in western Europe more than 300 miles from a port, and such ports as there are are usually well served by river or canal. It is impossible in this country to find one that is 100 miles from a port. Per ton mile transportation by water is far and away cheaper than by any other means. This is the reason for the slow development of pipelines in Europe, and particularly in this country, and the rapid development in the United States where there is an enormous land mass with 3,000 miles between coastlines. As a result, the economic incentive to build pipelines was much greater, sooner, in the United States, and so our construction techniques are largely derived from there.

Multi-product pipeline

Generally it is not worth while building a pipeline unless it is to carry 300,000 tons or more over about 70 miles. There is an incentive, therefore, in order to raise the total tonnage, to transport several products by the same pipeline.

The technique of transporting many different white-oil products through the same pipeline has been well developed in the United States, and a line for this purpose is about to be built in this country. It is intended to transport 11 different products in this line.

In such a line one product is followed by another simply by closing one valve and opening another simultaneously while keeping the pump running and so maintaining pressure on the line. There is a certain amount of mixing at the interface, and its magnitude has been determined empirically and is known very distinctly for all product patterns. As an example might be taken petrol/paraffin. In a 10-in. line initial mixing at the pump would be about 2 tons, and the quantity of mixed material would grow at the rate of approximately ¼ ton/mile. On a 100-mile pipeline, therefore, about 30 tons of mixed product would be received at the delivery end.

Mixed product is 50% degraded material at least fetching a lower price, and must be kept to a minimum. If ½% is the target, then the minimum acceptable batch is 6,000 tons.

The sequence in which the different products are pumped should be so regulated that the mixed material can be lost in the next lower grade. For example, when pumping premium motor spirit followed by regular spirit, the mixed material can be lost in the regular spirit because it merely slightly improves the quality of the latter. A quarter per cent. of the premium spirit has, of course, been downgraded, and would be sold at the regular spirit price, and account must be taken of this in the economics of the operation. By the same token, in a given case, if the mixture can be lost in the higher-priced product, there will be a financial gain.

As the rate of pumping and size of batch are known, the receiving end can be told within a few minutes when to expect a change of grade. The technique then is to take specific gravity readings by an almost automatic device designed for this purpose and incorporated at the receiving end of the pipeline and, at the appropriate moment, again by means of simultaneously operated valves, to switch the following product into its correct tank. The degree of mixing has been reduced to some extent in some U.S. operations by inserting pressurised hard-rubber spheres into the line between products. The technique is not as rewarding as may at first sight appear, owing to extreme wear on the spheres, caused mainly by rough welds. It also increases the complexity of installed equipment, and of operation.

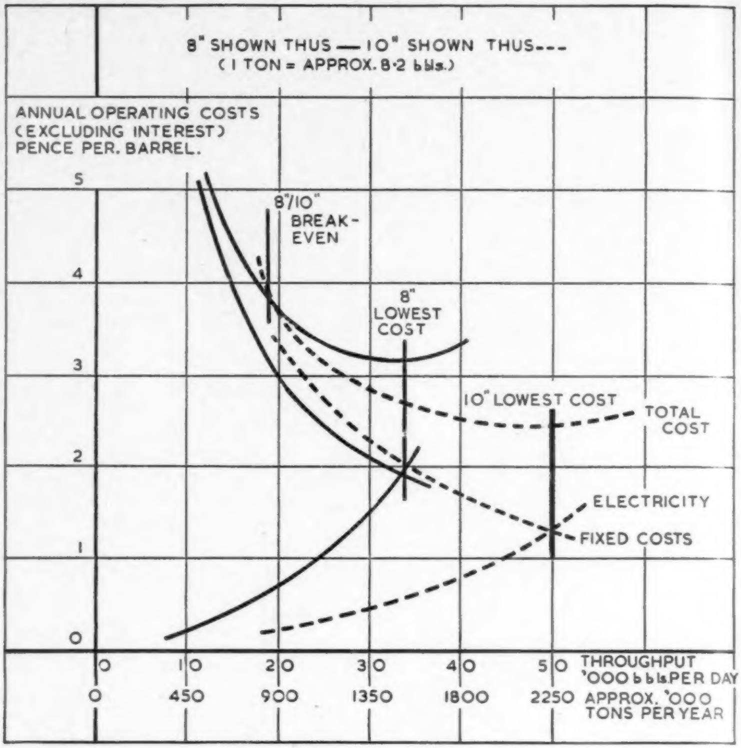
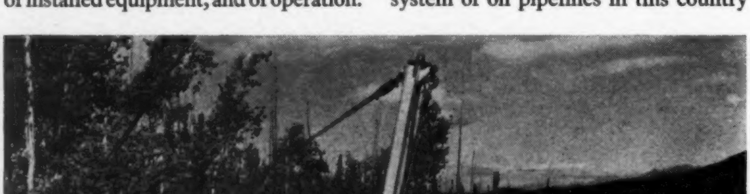


Fig. 1

There should be visualised, then, 'slugs' of product 60 to 70 miles long moving through the pipeline at 4 m.p.h. with about ½ mile of mixture between adjacent grades when the delivery point is reached.

General considerations

There is no question but that the system of oil pipelines in this country will be extended. Transportation of oil by pipeline is a naturally evolutionary development from the stages of 2-gal. cans transported by horse and cart, 4,000-gal. consignments in road and rail tankers, and consignments of hundreds of tons by coaster. The technique of transportation represents progress from a discontinuous to a continuous process which will be very familiar to those concerned with developments in the chemical industry. Oil product pipelines are closely analogous to the electricity grid, enabling the processing to be carried out where economically best and irrespective of the proximity of areas of high consumption. The gas industry also has been developing a similar pattern of pipeline distribution simultaneously with the oil industry and for virtually identical reasons.



[Courtesy: Williams Brothers Corporation

Caterpillar diesel tractor equipped with pipe layer sideboom is working on bending operations on pipeline construction between Haines and Fairbanks, Alaska

Pipeline through Eastern Europe

A 4,000-km. pipeline passing through the U.S.S.R., Poland, Hungary, East Germany and Czechoslovakia has almost been completed. It will be the longest pipeline in the world. Most of the Hungarian section of this pipeline will be on stream this year.

Pipelining in the Gas Industry

By W. E. Medhurst, M.I.Gas E., M.S.E.

The economics of gas transmission depend to a great extent on the proper selection of pipe diameter and working pressure. During the last few years the development of steel as a constructional material for pipelines has brought about new methods of pipelaying. This article describes the various operations that are carried out in modern pipelines whose success depends largely upon continuity of working.

PERHAPS the most obvious advantage obtained as a result of the national ownership of the gas industry is that over large areas of the country boundaries have been removed and undertakings have been brought together under the control of 12 large authorities. This reorganisation has resulted in the concentration of gas-making at selected works where costs are lower, and gas being transmitted to small works which have been closed down and converted into holder stations.

The economics of gas transmission depend upon a number of factors including laying costs, pumping costs, volume of gas pumped and pumping pressures. With each scheme there is an economic combination of diameter of mains and working pressure. Up to some ten years ago this economic pressure was low enough to be in the range suitable for use with cast-iron pipes. The transmission of gas was on a comparatively local basis; some systems had been constructed, but the mains had, to a large extent, been laid through built-up areas and along roads and paths. The presence of other services along these routes slowed down the rate of mainlaying and prohibited the use of mechanical excavating plant.

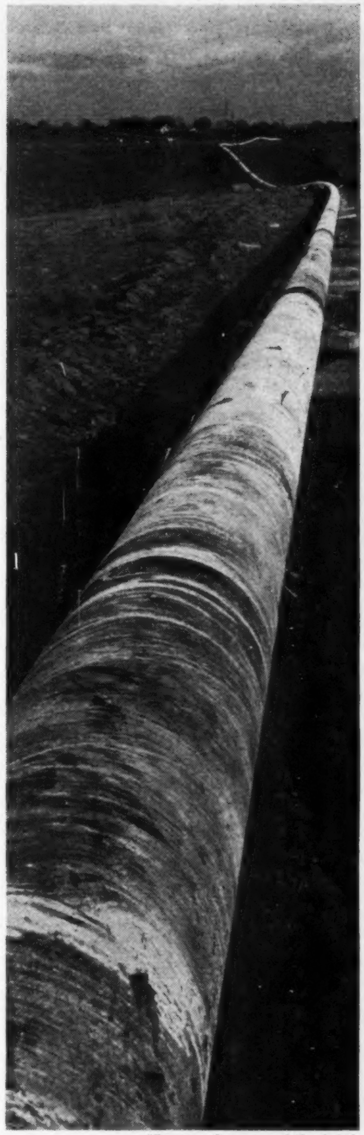
As the plan of integration developed and extended, so it became necessary to work at higher pressures. During this period, labour costs increased and resulted in higher costs of mainlaying. The net result of these two increases was that the economic diameter of main became smaller, with a resulting higher economic working pressure. These two factors led to consideration being given to the use of steel pipes for transmission mains and to new methods of pipelaying which had been in use in the U.S. for many years.

The development in the U.S. of thin-wall high-tensile steel pipe has resulted in a substantial saving by reducing the weight of steel required for a particular job. One advantage of a steel pipeline is that the system is flexible inasmuch as the pipeline carrying capacity can be increased by raising the working pressure. The tremendous amount of long cross-country pipelines constructed in the U.S. during the last 20 years has led to the development of highly organised and mechanised methods of pipeline construction.

In Great Britain the relatively close proximity of villages and towns and the characteristic small areas of land owned or farmed by one individual has, in general, prohibited the complete operation of American methods of pipelining. However, these methods have been slightly modified to suit the majority of British project conditions.

One of the first considerations to be made when examining a proposed pipeline scheme is its cost. A rough estimate is prepared, using a route obtained from the examination of a map followed by a quick field reconnaissance. If the project appears to be economic, a field survey is made to arrive at the exact route for the proposed main and, at the same time, the landowners are approached regarding the legal easements for the section of pipeline to be laid across their land.

It is preferable to have these easements for perpetuity and paid for by means of a lump sum per yard run of



[Courtesy: Stewarts and Lloyds Ltd.

12¾-in.-o.d. steel pipe which is protected externally with woven-glass-reinforced sheathing. Pipes welded along route prior to trenching operation. The pipeline contractors were William Press and Son Ltd.

pipe. This payment provides the right to construct, operate and maintain the pipeline and it may also provide for additional lines. Special provisions dealing with a specified amount of cover, restriction on the construction of buildings or other similar work on the right of way may, where necessary, be contained in the easement agreement. Railway, river and other special crossings require separate easements, in some cases with more than one authority.

The right of way negotiated in an easement is a working strip, usually 30 to 40 ft. in width. This strip must be wide enough to allow the movement of plant along the strip during the laying operations. The procuring of easements, etc., is the responsibility of the Gas Board who may employ qualified land agents to negotiate with the land owners or their agents, the final exchange of legal documents being dealt with by the two parties' solicitors. The Board's land agent would also deal with the question of compensation for loss of crops, etc., on the completion of the work.

The success of modern pipelining depends upon a highly organised continuity of operation of several specialised units of men and plant working along a section of the pipeline. This group of units is referred to as a 'spread' and on a long job there may be several 'spreads' working.

The normal units in a 'spread' and the work done by them is as follows:

(1) Clearing and grading unit

This unit is first to go into action and the crew will clear the working strip in advance of all operations. Hedges, fences, etc., are removed and replaced by temporary fences, trees and bushes are taken up and removed from the site. Temporary timber bridges are erected across ditches and, if necessary, the width of the right of way is graded to allow a trench digger to work. In some areas the depth of good crop-growing soil is very little and in these cases a suitable depth of top soil is bulldozed to one side of the working strip so that it may be replaced on the completion of the work.

This unit would also construct temporary roads which may be required in order to transport pipes, etc., from a hard road to the pipeline.

(2) Hauling and stringing unit

The stringing crew follow up behind the clearing unit and their job is to lay or 'string out' the steel pipes along the right of way.

The pipes, which are usually 30 to 40 ft. long, are transported by pipe trailers from pipe dumps or directly from railway wagons or transport lorries.

(3) Welding unit

The welding crew weld the pipes into a continuous pipeline. The number of welders used depends on the diameter and thickness of the pipe; a typical crew would be six welders in three groups of two per group. Each pipe is delivered to site with ends bevelled for butt welding and these ends must be filed or wire brushed to remove rust and foreign matter.

An internal or external clamp is used to hold the pipes in position while two welders apply the first weld, called the 'stringer bead'. When this weld is made the clamp is removed and fitted to the following pipe and the 'stringer bead' welders move with it; they are followed by two more welders who apply a second weld over the 'stringer bead' called the 'hot pass'. This second crew then move on one joint and are replaced by two more welders who apply the 'filler bead' weld and a 'capping bead' weld.

It can be seen, therefore, that at any one time three joints are receiving attention and that the operation is a continuous one. The weld is made using the 'downhand' method, commonly called 'stovepipe welding'. It is a method which has been developed for use in connection with pipelining and is a much quicker method than the orthodox uphand weld.

All welding is carried out to a very close specification, and it is usual to employ specialist engineers to supervise and inspect the welding work. Each welder has to pass a test before commencing work on the site and every weld is marked to correspond with a welding operator.

The method of testing a finished weld varies, but the two main methods employed are:

(*a*) *Radiographic*. This depends upon the ability of gamma rays to penetrate matter according to its density, thickness and its atomic number. Defects in a weld result in a variation in the gamma-ray beam intensity and this variation is recorded on a film strip.

(*b*) *Ultrasonic*. This is based on the use of ultrasonic waves which are transmitted through the weld. The passage of these waves is upset by a flaw or other discontinuity in the weld and this variation in the wave is picked up by a receiving head and is indicated on a cathode-ray oscillograph.

The percentage of welds tested depends on the specification, but, if radiographic methods are used, 100%

Ultrasonic 2½-m./c./sec. weld tester being used on 24-in. Stewarts & Lloyds steel pipes for conveying refinery gas from Shell Haven oil refinery to Romford

testing is carried out at the start of a project, reducing this percentage as the work proceeds and taking spot tests at random. Certain important welds would, however, be tested in any case.

When ultrasonic testing is used, it is usual to test 100%. Suspect welds are sometimes checked using the radiographic method.

(4) Testing

In general, convenient sections of pipe are tested during the pipelaying operation and a final test is made after the pipe has been laid and the trench filled in. The sectional tests are made using air at about 50 p.s.i. and when under pressure each joint is inspected. A further sectional test may be made after the main has been laid in the trench and covered up. This is usually a hydraulic test made at maximum design pressure plus a safety factor of, say, 50%. This test proves the mechanical strength of the main and fittings.

The final test would be a hydraulic one similar to the sectional test and this would be followed by an air test of perhaps 100 p.s.i. to prove the line for leaks. Any pressure drop would be recorded on special pressure gauges which have to be corrected for barometric pressure changes.

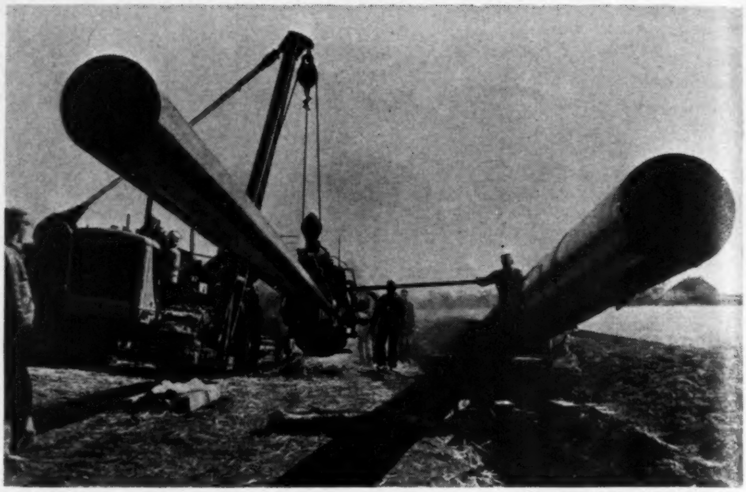
(5) Pipe coating

Pipes may be received on a site already coated at the manufacturer's works. If this is so, then it will be necessary to complete the coating at the joints.

The whole pipe coating is tested for imperfections and pinholes, using an electrical ' holiday ' detector. This machine generates a high-tension current which is fed to the pipe and to a mobile copper brush. The brush is moved over the surface of the coating and any hole or ' holiday ' would allow a discharge to take place between the brush and the pipe. All defects must be made good before the pipe is lowered into the trench.

If the pipe is not coated at the works then this operation can be carried out at a site depot or can take place after the pipe is welded in a line. In the latter case a cleaning and priming machine is passed over the pipe and travels along the welded-up section. The front end of the machine consists of revolving brushes which clean the pipe and prepare it for priming, which is carried out by the rear end of the machine.

When the priming coat is dry a second machine travels along the



[Courtesy: Northwestern Utilities Ltd.

Stewarts & Lloyds 16 in. o.d. × 0.375 in. × 62.5 lb./sq.ft. Completion of the third transmission line into the City of Edmonton, Alberta, Canada

pipeline and applies a coating of bitumen or coal-tar enamel about $\frac{1}{8}$-in. thick. Simultaneously a fibre-glass strip is pulled in to act as a reinforcement. A second fibre-glass strip is sometimes pulled in just below the outer edge of the coating.

The whole coating may then be covered by a strip of paper wound round the pipe to prevent sticking. On completion the coating is tested with a holiday detector as described above.

(6) Trench excavation

This unit follows behind the pipe-coating crew. There are many excavators in use and they do not need description. On a long run of pipe across country the wheel-type excavator is often used and it is capable of taking out a trench 2-ft. wide and 3 ft. 6 in. deep at a rate of one mile per day in good average ground.

Great care has to be taken in some areas where land drains are laid in fields. These drains are important and must be replaced or flooding of the land will occur.

(7) Laying unit

The completed line is flexible in long lengths and side-boom tractors travel along the side of the trench and lower the pipe in stages. Special slings are used in lifting the pipe so as to avoid damage to the wrapping.

(8) Backfill and restoration unit

Sub-soil is replaced by this crew. It is important to ensure that soil is rammed well down the sides of the pipe so that the space between the underside of the pipe and the trench is filled. If this is not done, sinkage of the soil will occur at a later date. It is usual for a Board to ask that the initial filling in should be punned in layers about 1 ft. thick.

Land drains crossing the trench must be repaired and supported on a sound foundation.

Finally, the top-soil, which had been stacked on its own, is spread back over the width of the working strip.

Restoration of hedges, gates, etc., will follow and it may be necessary to carry out certain cultivation operations along the right-of-way.

Laying to ground contour

Normal untreated gas is saturated with water vapour when it leaves a gasholder. Changing pressure and temperature conditions below ground may cause some of this water to condense out into a liquid state and, unless this is collected and removed, it is possible for the main to be blocked at low points.

Condensate receivers are fitted at these low points and the water is removed from them at regular intervals.

True pipelining methods require a main being laid to the contour of the ground, *i.e.* at a uniform depth and with the minimum of excavation. If a gas transmission main is to be laid using 100% pipeline methods then the gas must be dried before it enters the main. This will avoid the use of condensate receivers along the line. It is known, however, that most of the water vapour still remaining after a saturated gas has been compressed and cooled is deposited within the

first mile or so away from the compressors.

It is sometimes found to be more economical to fit condensate receivers for this first mile or so and thereafter to lay the main to ground contour than to dry the gas after compression and to lay the whole main to ground contour.

Line 'pig' or 'go-devil'

Before a line is put into operation it is usual to pass a 'gauging pig' through the main to remove dirt, foreign substances and small pieces of weld metal which may protrude into the pipe at a joint. The pig is made up of a centre spindle on which are fitted three or four large cup washers, which form a fairly tight fit inside the main. A gauging pig has a hard steel circular plate fitted at the forward end of the cup washers. The diameter of the plate is about $\frac{3}{8}$ in. less than the inside diameter of the pipe.

In a pigging operation the pig is inserted into the main and air is pumped into the main behind the pig. Air pressure causes the pig to move forward at a controlled speed. The steel plate will cut off any weld metal and carry it forward, together with any other substances, to the far end of the pipe run.

A 'swabbing pig' is similar to a gauging pig, but it is not fitted with the steel plate. Its use is to clear water and dirt from the main and provision is generally made to enable a gas line to be pigged even if dry gas is being transmitted.

Special receiving and transmitting traps are constructed at each end of the pipeline in order to insert a pig into the line and to remove it under working conditions.

The success of a pipel'ning spread depends upon continuity of working and highly organised units of men and plant. Any factor likely to hold up any unit must be dealt with in advance. It is for this reason that small gangs would be employed along a pipeline route laying pipe in special positions such as beneath railways, rivers and important highways.

These specialised operations present many engineering problems and result in new methods being devised.

One interesting machine now being used is the *Auger* borer. This plant is capable of boring a horizontal hole up to 24 in. diam. for a distance of 300 ft. As the hole is drilled a steel sleeve is fed forward and on the completion of the work the steel sleeve is left in the ground and the gas line passed through it.

Cathodic protection

It must be assumed that the protective coating of a pipeline is not 100% complete. Stones on the trench bottom and in the backfill may possibly damage the coating and, with certain types of soil, corrosion will follow.

Corrosion of a metal buried in soil results from electrolytic action between the metal and the moisture present in the soil. Dissolved salts and gases (principally oxygen) in the water act as the electrolyte.

Corrosion is always associated with a flow of current from the metal into the electrolyte, *i.e.* the pipe becomes anodic at the point of corrosion. If sufficient current can be caused to flow into the exposed metal from the electrolyte then the current flow outwards is stopped and metal ions cannot pass from the metal and the metal becomes cathodic.

There are two methods of doing this:

(*a*) By connecting to the pipe an anode made of a metal more positive than the pipe metal, *e.g.* zinc or magnesium. This is known as the sacrificial anode method and depends upon the natural voltage difference developed between the two metals.

(*b*) The power impressed system which uses an inert material such as graphite and applying a d.c. supply for the driving power.

Both methods (the first to a lesser extent) may adversely interfere with other underground plant in the area of operation. Careful tests must be carried out and, if necessary, special arrangements made to reduce this interference to a safe limit.

[Courtesy: Williams Brothers Corporation

Making final weld on pipeline construction job between Haines and Fairbanks, Alaska

[Courtesy: Stewarts and Lloyds Ltd.

Welding ends on 24-in. Stewarts and Lloyds steel pipes for conveying refinery gas from Shell Haven oil refinery. These pipes are protected externally against corrosion by woven-glass-reinforced sheathing. The main laying contractors were William Press and Son Ltd.

Plastic Pipes and Pipelines

By C. H. Tetherton*

The plastic material most widely used as constructional material for pipes and pipelines is unplasticised PVC, which has only been known in Europe since the end of the second world war. This article reviews the properties and applications of PVC pipes, especially with respect to existing standards and methods of joining fittings.

THE widespread acceptance of plastics as materials of construction has undoubtedly been hampered by the difficulty found in correlating physical properties with behaviour in actual use. The situation is further complicated by the many kinds of plastics available and the variety of formulation of each. Plastics have unique properties which can be used to good advantage and, with a specific purpose in mind, materials can be compounded to meet certain requirements. Whilst the limitations of a given compound must be recognised, plastics are a considerable advance over conventional materials and should be considered in this light rather than as substitute material where cost is, by necessity, required to be lower.

During the initial development of plastic materials in the field of pipes and pipe fittings, it was very noticeable that designers and engineers held this view, but when a better assessment of the properties of the material was made, opinions altered, and the view now held is that the added advantages were considered worth while even if the material became more expensive. From the design angle the first considerations are the specific conditions which must be satisfied.

Unplasticised PVC was developed in Germany over 23 years ago as a substitute, but rigid PVC pipe soon proved its independent worth. Since its introduction into America in 1950, it has lived up to its European reputation as an outstanding material of construction for pipe, valves and ducts and is termed Type 1. Comparable material has been in use in the U.K. for several years and is known as normal-impact PVC. It has an Izod notched impact resistance in the order of 1 ft.-lb./in., and is resistant to all salts, alkalis and non-oxidising acids. Although this impact value appears to be extremely low, it is much higher than many materials of construction. For quality control test, Izod impact has been replaced by a falling-weight test which has a closer relation to service conditions. Pipe may be crushed in a vice without cracking and a hard blow from a 10-lb. hammer is required to cause fracture.

An ever-lengthening table of corrosion-resistance data supplied by all manufacturers gives an indication of the extensive range of materials for which unplasticised PVC can be used, with the temperature range recommended.

One of the products developed with the object of increasing impact resistance is a blend of polyvinyl chloride and acrylonitrile rubber. This material, whilst being slightly less resistant than Type 1 or normal-impact PVC, is known as high-impact PVC and has an impact resistance of up to 15 ft.-lb./in. of notch. In chemical resistance tables these materials are listed side by side with recommended concentrations of certain corrosives. The choice of either of these two materials may be determined by the corrosive nature of the material to be transported.

Bursting pressure

The second consideration should be the bursting pressure and allied with this the allowable working pressure.

Since the strength of unplasticised PVC decreases as the operating temperature is increased, it is necessary to decrease the allowable working pressures at higher temperatures. Working pressures are usually stated in tables at 75°F. and are about 20% of the burst pressure. When operating temperatures exceed 75°F. the maximum operating pressure should be determined from graphs which take the creep strength of the material into account. To determine the maximum operating pressure at any temperature the maximum operating pressure at 75°F. must be obtained from a table given. The value has been plotted against the maximum operating pressure for temperatures between 50°F. and 150°F. for normal-impact PVC.

A similar chart is available for high-impact PVC. The maximum operating pressures decrease with increasing temperatures in a manner similar to that for normal-impact PVC, up to 110°F. Above 110°F. creep extension (a time-dependent extension which occurs at stresses lower than the yield strength) becomes significant, so that the pressure rating chart must be based on creep characteristics of the material in the range of temperature from 110° to 130°F. Having taken the maximum operating pressure at 75°F. from the table, which shows values for nominal-bore pipe, plain and threaded in two ranges of wall thickness, maximum operating pressure for any required temperature can be read from the graph provided.

Comparison with metals

PVC pipes and fittings have characteristics which are superior to metallic systems in numerous applications. Among these are:

(*a*) Adaptability to existing installations
(*b*) Corrosion resistance
(*c*) Less frictional loss
(*d*) Lower installation cost
(*e*) Minimum maintenance costs
(*f*) Ease of installation
(*g*) Light weight
(*h*) Resistance to most chemicals
(*i*) Resistance to weathering, ageing and aggressive soil conditions
(*j*) High effective strength
(*k*) Maintenance of high fluid purity

An industry in which PVC pipe has an important part to play is the water industry. Special requirements to prevent toxicity are being met by raw

**Production Manager, PVC Moulding and Extrusions, BTR Industries Ltd.*

material suppliers and these are being evaluated by extruders and injection moulders.

The difficulties in meeting the needs of water engineers and at the same time manufacture compounds which can be satisfactorily stabilised for easy processing should not be minimised. From the design angle the selection of the proper plastic for the purpose in hand is in accordance with standard engineering practice:

(1) To define performance requirements
(2) To select material which best meets these requirements
(3) To analyse the economics involved

In industry, particularly the chemical industry, the requirements are generally reduced to:

(*a*) Corrosive conditions
(*b*) Pressure requirement
(*c*) Temperature at which pressure is to be maintained

One of the most important aspects of piping is that it should conform to some standard dimensionally and, whilst no official standard has been issued, manufacturers generally are all working to a range of nominal inch bores with standard outside diameters which accord with B.S. 1387 for threaded pipe sizes. This range of outside diameters of pipe is also in accordance with American pipe sizes in range $\frac{3}{8}$ in. N.B. to 6 in. N.B. and is being extruded in this country with wall thicknesses in line with Schedule 40 and Schedule 80 pipe as American standard. This arrangement has some very important advantages for the engineers or designers because it means that years of accumulated test data are available for reference.

A section of the BTR 'Silverflow' PVC system at Murgatroyd's Salt & Chemical Co. Ltd. showing storage tanks in the background to which sodium hypochlorite liquor is conveyed. Similar piping is also used in this factory for the handling of hydrochloric acid

Since threading pipe reduces the wall thickness of standard wall piping excessively, it is not recommended that Schedule 40 pipe be threaded but it is standard practice in Germany and America to thread Schedule 80 pipe, the wall thickness being adequate for this purpose.

The threaded pipe size has been an important factor in determining standardisation of outside diameters, and Schedule 80 and 120—the extra-heavy wall PVC pipe—can be threaded by using standard metal thread-cutting tools, either machine or hand operated. A standard cutting tool dressed to have a negative rake angle of 5° is recommended where there is considerable volume of threading work. The material is easily threaded without the use of external lubricants. Thread dies should be maintained in good condition to produce sharp, clean threads. When pipe is gripped in a vice or chucked for threading, some type of protective wrap, such as canvas, should be used in order to avoid scarring the pipe; also it is advisable to insert a tapered plug into the end of the pipe to hold the pipe circular whilst it is being threaded. This results in threads which are of uniform depth circumferentially. It is important to follow recommendations concerning thread length, because if the threaded portion is too long it is impossible to run the fitting on far enough to obtain a good seal.

Joints can be effectively sealed with the standard thread compounds, depending on the medium to be carried. For extreme chemically resistant application a threaded compound based on the tetrafluoroethylene resins should be used. This compound acts as a lubricant as well as a chemically-resistant seal. A more convenient method is to use a special PTFE tape which is lapped tightly over the threaded portion and overlapped by $\frac{1}{2}$ in. This tape bites into the thread when the fitting is screwed on and remains flexible indefinitely, thus making dis-assembly easier and ensuring a satisfactory seal at all times. It should be noted that threading is made to B.S.P. standard taper thread on both pipes and fittings. To ensure a positively leakproof joint, two or four threads past hand-tight is recommended.

Solvent weld joining

One of the important advances in pipe joining technique is the solvent weld method which requires socket-type fittings. By this method the full strength of the pipe is assured and higher working pressures can be used than with threaded pipe systems.

The Schedule 40 pipe, which is too light in wall thickness for threading, can be joined by this method.

The design of all socket fittings are such that socket diameters will accommodate the maximum outside diameter of extruded pipe to enable fittings to be assembled dry with ease. This feature is essential when assembling pipework in confined spaces and allows the adjustment to be made before final welding. The socket has a slight taper so that the outside diameter of the pipe is in full contact when almost touching the shoulder at the bottom of the socket.

Pipe to be joined should be cut with an ordinary handsaw or power

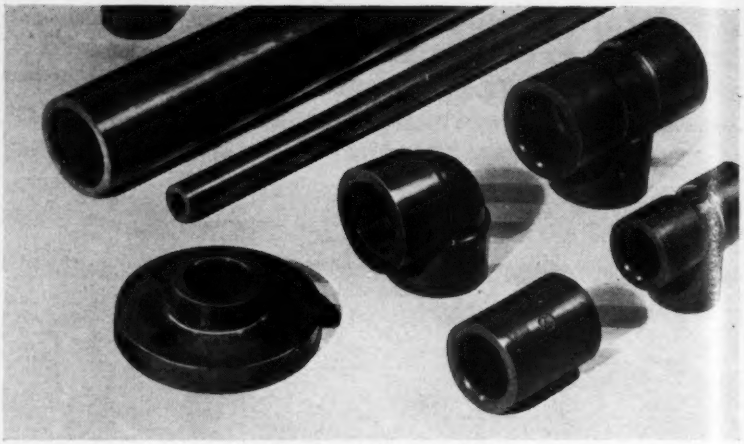
saw. Cleanest cuts are obtained if fine-tooth blades six to nine teeth/in. with very little or no set are used. A mitre box will ensure that the pipe is cut square. Ends of the pipe should be deburred with a fine file. In cases where the pipe is too large, emery cloth may be used to remove excess material so as to provide a cylindrical end portion of sufficiently reduced o.d. for a proper fit. All connecting surfaces should be clean and free of dirt, grease and other foreign materials. It is recommended that the pipe ends and fitting sockets be wiped lightly with a cloth moistened with methylethylketone or acetone. Using an ordinary paint brush of width about equal to the nominal pipe size, a generous coat of solvent is applied and is welded to the inside and shoulder of socket, flowing on but not brushing out, so that the entire gap between fitting and pipe will be completely filled. A similar coat is then applied to the end of the pipe for at least the same distance on the pipe as the depth of socket and to the cut end. Pipe and fitting are then firmly pressed together and the pipe turned a quarter to half turn when bottomed in socket, to evenly distribute the cement. The cementing and joining operation must not exceed 1 min. If the proper amount of cement has been applied, a fillet of cement will form and the excess will be drawn back into the joint. Joints should not be disturbed for 5 min. if at room temperature; longer at lower temperature.

Relative motion between the cemented pieces should be avoided, as handling strength is not developed for about 30 min. This kind of joining gives rapid assembly. A pipe-laying crew made an installation of 2-in. pipeline in Texas, laying the 2,800-ft. line in less than 1 hr. 45 min.

Working strength of a solvent welded joint is not reached until 48 hr. or longer. However, in most instances, pressures up to 10% of working pressure may be applied within 4 hr. at 75°F.

Solid flanges are recommended with flange thickness of sufficient stiffness to obviate the necessity for a steel backing flange. When solid flanges are used with full-face neoprene or plasticised PVC, $\frac{1}{8}$-in.-thick gaskets are suitable for working pressure of 150 p.s.i. at a temperature of 75°F.

The flange is constructed with ample margin of safety for higher working pressures, the limiting factor being the efficacy of the gasket to seal the blow-out pressure. Neoprene, PTFE or plasticised PVC 'O' ring



BTR 'Silverflow' PVC pipes and fittings

gaskets should be used with bolt stress maintained between 10,000 to 15,000 p.s.i. Increasing bolt stress to 20,000 p.s.i. does not appreciably increase the leakage pressure, but may distort flange.

Fillet welding

As an alternative to solvent welding the flange may be fillet welded by a hot-air gun. When attaching flanges to fittings by solvent weld method to enable bolted assembly, it is essential to line up the bolt holes. In order to assist this operation, flanges are quarter marked by raised lines which coincide with lines on fitting. All flanges have a convex taper on flange face designed, after exhaustive tests, to ensure proper sealing inside the bolt circle.

Thermal expansion due to temperature variation must be taken into account in considering any pipeline in unplasticised PVC.

The linear coefficient of thermal expansion for normal-impact PVC is 2.9 to 4.6 $\times$ 10^{-5}/°F. and 4.5 to 5.6 $\times$ 10^{-5}/°F. for high-impact or rubber-modified PVC.

Compensation

A major problem in design is to provide adequate compensation for expansion and contraction. The lyre-type bend and square-type expansion bends are effective, but ruled out on many pipe installations for reasons of economics and practicability. Slip-type expansion joints are now available in sizes 1 to 6 in. normal- and high-impact PVC, all sizes allowing for an expansion of $3\frac{3}{4}$ in. The sliding member is provided with neoprene 'O' ring packing and is suitable for a wide range of corrosive services. This type of expansion joint, of in-line design, takes up a small space and can be adapted to piping of smaller diameters by employing reducing bushings.

If a PVC pipe run is constrained at the ends and expansion is restricted, stresses of the order of 900 p.s.i. may be imposed on the pipe. The following formula will be of assistance in determining the longitudinal stress that may be developed by restrained thermal expansion:

$$S = CE\,(T_2 - T_1)$$

where S = expansion stress, p.s.i.; C = coefficient of thermal expansion, °F.$^{-1}$; E = modulus of elasticity in tension, p.s.i. (400,000 for normal-impact PVC and 350,000 for high-impact PVC); and $T_2 - T_1$ = operating temperature range, °F. or maximum spread between installation and operating temperature, whichever is greater.

If S is greater than 550 p.s.i. (for socket joints) at 75°F. or 350 p.s.i. at 140°F., compensation is required. Constraint is not recommended with threaded systems unless fittings are isolated by clamping.

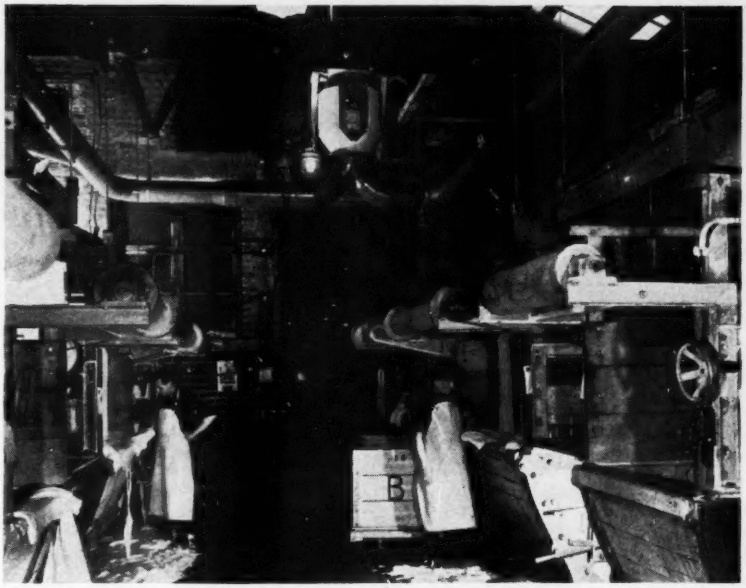
In certain cases the amount of expansion take-up can be provided by pipe directional changes and pipe flexibility. A rule of thumb is that pipe can be permitted to take up as much side deflection as the pipe would normally flex under its own weight if supported in a cantilever fashion. The floor of the trench should be as smooth as possible to avoid bending stresses. As in all systems, pipes should be laid below the frost line to eliminate stress caused by possible freeze-up.

Backfilling

Backfilling should be carried out by providing a bottom cushion 6-in. thick, then a 6-in. layer of loose material—

both free from rocks and sharp objects—should be placed on top of the pipe.

Standard backfilling procedure can be used to complete the operation. During installation it is wise to weigh down the pipe at about 75-ft. intervals to prevent arching due to ambient temperature changes. Where the pipe must bear heavy loads, such as in installation under roadways, it is recommended that the pipe be protected by an external oversize casing.



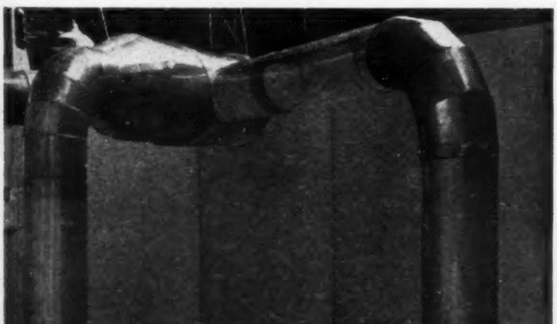
'Darvic' PVC fume canopies and ducting made and installed by Extruded Ltd., at the works of W. E. Saxby (Nottingham) Ltd.

Supports

Supports for PVC pipes should be spaced at intervals one-quarter to one-third the length of those used for steel pipe. Saddle-type hangers are suitable. When threaded fittings are utilised in a system which undergoes large thermal fluctuation, stresses at the fittings from thermal contraction or expansion can be avoided by clamping the pipe tightly on both sides of the fitting, thus restricting defection at the fitting. This is specially important at 90° turns, since bending stresses are imposed on the pipe at the threaded portion by thermal contraction or expansion if the pipe is allowed to move freely.

As the operating temperature is increased, it is necessary to decrease the support spacing. Pipe insulation, due to its weight, also necessitates closer spacing. Consideration should be given to continuous support for insulated lines operating at higher temperatures. Recommended support spacings for pipe installations are given by pipe manufacturers, but continuous support should be provided for temperatures above 120°F. for normal-impact PVC, and above 100°F. for high-impact PVC.

It is also recommended that all valves and other concentrated loads (such as tees, flanges, etc.) be supported independently of normal span support. Metal bonnet valves should be fully supported. Lines should be continuously supported above the higher temperatures given when used for hazardous services and when the cost of individual supports becomes higher than the cost of continuous support.



Fume ducting prefabricated by Chemical Pipe & Vessel Co. Ltd., from 'Darvic' rigid PVC manufactured by I.C.I. Ltd. Plastics Division

Hangers

The types of hangers which should be used are adjustable clevis, ring or roll hanger and roll stands with broad support surfaces. Hangers to be avoided are those which clamp pipe rigidly and constrict it.

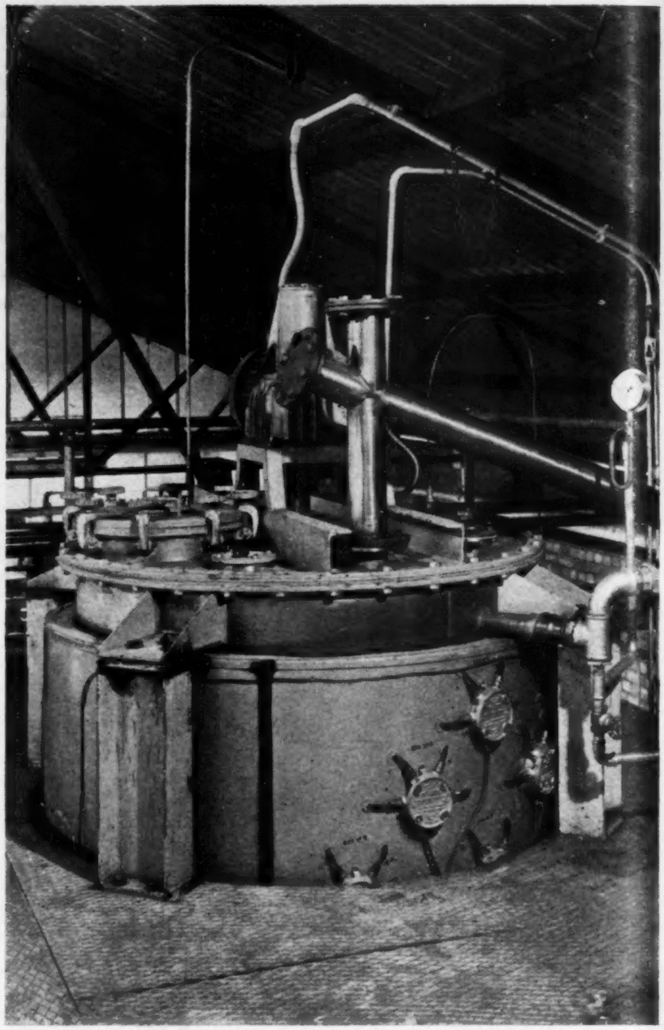
A pipe clamp must not force the pipe into position. Therefore, each section of the pipeline should be laid out and all connections (cemented, welded or screwed) should be made whilst the pipe is held on temporary support, and after the completion of these connections the final clamping should be done. When piping is correctly installed a clamp, holder or pipe connection can be loosened or taken away and the pipeline will not change its position.

In considering a PVC pipeline as a complete system the question of valves will also arise. Diaphragm valves with unplasticised PVC and PTFE diaphragms are finding wide acceptance in the chemical industry as are the plug valves with 'U' PVC bodies with PTFE self-lubricating bearing buttons. Lift check valves and foot valves are obtainable in $\frac{1}{2}$ to 3-in. range capable of working with 6 p.s.i. differential pressure.

ACHEMA EXHIBITION PREVIEW

★ FRANKFURT-AM-MAIN ★
JUNE 9 to 17, 1961

Achema, probably the world's most comprehensive exhibition of chemical plant and machinery, will take place from June 9 *to* 17, 1961, *in Frankfurt-am-Main, Germany. More than* 1,300 *exhibitors from all over the world will be participating. In this preview we survey some new developments in chemical engineering that will be shown at the exhibition.*



Upper part of 500-gal. process vessel heated by flameproof 'Isomantle'

'To provide a complete survey of the progress which has been achieved in chemical engineering'—that is the avowed aim of the Achema chemical engineering exhibition-congress which is part of the European Convention of Chemical Engineering.

The first Achema exhibition was held in 1920 to promote research and development in the field of chemical engineering and chemical technology. Since then there have been 12 other such congresses. The last one, which took place in Frankfurt-am-Main in 1958, was attended by more than15,000 registered congress members, including 550 representatives of the press and about 65,000 professional people from 56 countries. The 1961 exhibition is estimated to be 14% larger than the 1958 exhibition. It will comprise 23 halls having an area of 764,000 sq. ft. of stand space and 118,000 sq. ft. of stand space for the outdoor exhibits to accommodate more than 7,000 items of equipment and instruments, chemical plant, structural machinery, factory supplies and auxiliaries for the chemical industry.

Besides the Achema congress there will be the annual meeting of Dechema, a special meeting of the Gesellschaft Deutscher Chemiker and a symposium organised by the Arbeits Gemeinschaft Korrosion. A congress is also arranged at which short papers will be presented on new research and development in chemical engineering science and technology. Papers will be presented on the following main subjects: Mechanical processes, technology of organic chemistry, separation of heterogeneous mixtures, technology of inorganic chemistry, rectification and extraction, water and gas purification, heat transfer, control and measurement, gas chromatography, concentration measurement, steels, structural materials and corrosion, non-ferrous metals, laboratory techniques, nuclear technology and use of isotopes.

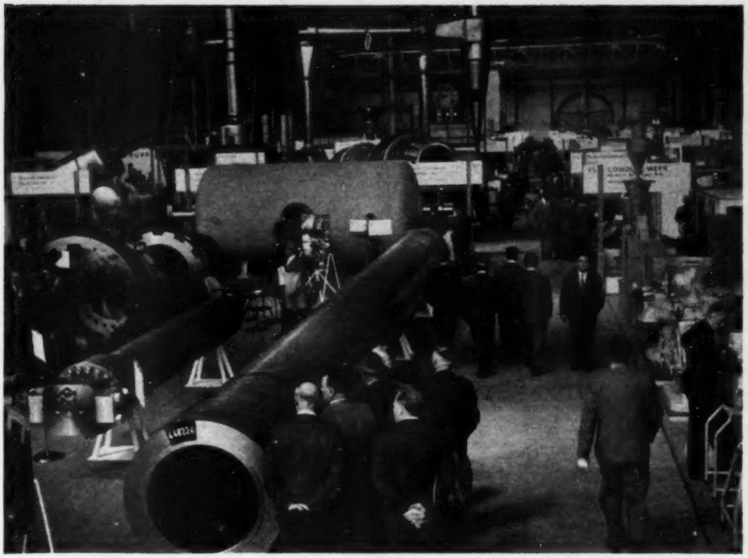
There will also be an Achema study course for senior students which will provide participants with facilities of

a systematic study of chemical plant, machinery, structural materials and auxiliaries at the exhibition.

According to Prof. Karl Winnacker, chairman of Dechema, three characteristic features, which are of importance to the future of chemical technology, were clearly noted at the 1958 congress. They are, firstly, to classify the vast amount of experimental results as rapidly as possible and to eliminate the non-essential matter so that the chemist and engineer are still able to review the subject matter. There must, however, be a possibility of surveying the whole field of chemical engineering. By including the field of nuclear engineering in Achema this problem has been overcome. Secondly, the largest proportion of registered visiting members at the 1958 exhibition came from outside Germany. Thus Achema congresses have become centres for international exchange of experience on an ever-increasing scale. Finally, the 1958 congress revealed that the maximum attention must be paid to teaching and research on the fundamental principles of chemical technology, physics, physical chemistry, industrial chemistry and process engineering. The closest possible connection must be maintained between the practical technologist in industry and the scientist in the research institution. For this reason more space is being devoted to the activities and reports of scientific research organisations in the Achema year-book.

This congress will, therefore, prove of utmost value to every chemical engineer in whichever part of the chemical industry he is engaged. The importance of this year's exhibition is perhaps enhanced, due to the economic integration of Europe. The two trade groups, European Economic Community and European Free Trade Area, are coming into effect this year and their viability will depend to a large extent on the prosperity of the chemical industry.

It is impossible in a preview to mention all the 1,300 exhibitors; we shall therefore limit ourselves to selecting several exhibits which we feel are of particular interest.



Great interest was shown in the full-scale plant on view at the 1958 ACHEMA exhibition

Another view of chemical plant shown at the 1958 exhibition

Electric surface heaters

Isopad Ltd., of Boreham Wood, Herts., will show their electric surface heaters in co-operation with their German branch, Isopad GmbH., Siegen. The exhibits include the latest developments of heating mantles for process plant, drum heaters and heating tapes as well as a full range of *Isomantles* for laboratories. Various examples of manual and fully automatic controls are included in the exhibits.

Filters and centrifuges

The exhibits of Krauss-Maffei-Imperial GmbH. & Co. mainly stress mechanical and thermal solid/liquid separation. Of particular interest are the newly developed pan-type and disc-type press filters and immersion filters. Visitors will have the opportunity to see these at the stand.

Press filters are used if a very dry solids cake is required. For this purpose the cake is pressed by means of a press stamp at a pressure of up to 20 atm. after previous vacuum filtration. The pan-type press filter allows for a thorough washing of the solids. The disc-type press filter offers the advantage of arranging the filter surface in a small area.

The immersion filter permits a good washing of the filter cake which is completely covered with liquid. The washing period is independent of the filtration period.

Continuously-operating centrifuges are displayed, for example a special multi-stage pusher centrifuge which has a particularly high throughput.

Magnetic flowmeter

J. C. Eckardt A.G. are exhibiting a large number of control instruments. Amongst these are instruments to determine conductivity, *p*H meters and fittings. Several years were required to develop the magnetic flowmeter. This instrument is particularly suitable for use with materials having a high viscosity or for abrasive substances with a high rate of flow. A prerequisite for using the flowmeter is that the material whose flow is to be measured must have a certain degree of electrical conductivity.

The operation of the magnetic flowmeter is based on Faraday's law of induction. An electromotive force (e.m.f.) is produced in an electrical conductor which moves across a magnetic field, and is proportional to the speed of movement of the conductor. Two stainless-steel electrodes are arranged diametrically inside the walls of a tube so that the inner surfaces of the latter are completely flat. The e.m.f. is led off from these electrodes to an appropriate indicating device designed as a self-equalising follow-up system. The measured value is constantly compared with the voltage from a potentiometer. As the magnets of the measurement transmitter and of the potentiometer in the electrical compensator are fed from the same supply mains, the readings are independent of variations in voltage. The measurement transmitters are supplied for various ranges of pressure and rated-tube diameters.

Corrosion protection

The flame-spraying gun exhibited by Colarit-Korrosionsschutz GmbH. has been developed due to a need to provide surfaces with adequate corrosion protection.

The large variety of applications for which this flame-spraying gun can be used, combined with the simple handling of the equipment, make it particularly useful for the application of thermosetting enamels.

The Colarit flame-spraying gun consists basically of a combination of the conventional paint-spraying gun operating on compressed gas, which has been slightly modified for this particular purpose together with a variable gas burner. This makes it possible to adjust the size of the burner flame from that of a small pilot flame with low temperature to that of a long, hot flame with temperatures up to about 800°C. The air needed for combustion is drawn into the combustion chamber by the injector action of the fuel gas flowing towards the forepart of the gun. This eliminates the need for a separate oxygen or air feed line that would require adjustment by hand.

Centrifuges and mixers

Carl Padberg Zentrifugenbau GmbH. are exhibiting various types of centrifuges and mixers. The *Cepa* high-speed centrifuge is suitable for industrial and laboratory purposes and can attain speeds of 14,000 to 45,000 r.p.m. It is therefore suitable for clarification of liquids. In many cases paste-like fluids can be continuously separated from liquids. The capacity of this type of industrial centrifuge is 200 to 3,500 l./hr. They are supplied in stainless steel or bronze and are also supplied with pumps, heating installations and electrical switchgear.

Cepa high-speed mixers are being constructed for open and partially closed containers—their speeds range from 300 to 1,400 r.p.m. These mixers are suitable for intensive mixing and homogenisation of liquids in containers with capacity up to 3,000 l. at viscosities of 2,500 cp. Optimum mixing efficiency can be obtained by altering the inclination of the mixing paddle in a vertical or horizontal direction.

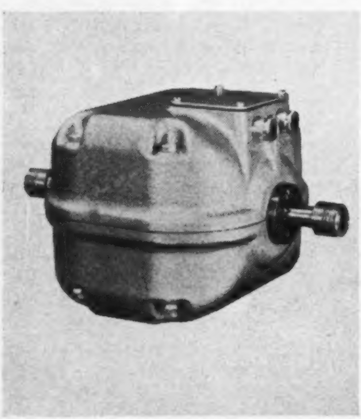
A new laboratory stirrer is being shown for the first time which can be entirely enclosed to protect it against dampness and steam. The mixing bowl capacity can range from 3 to 20 l. capacity for pressures ranging from atmospheric to 40 atm. and temperatures up to 200°C.

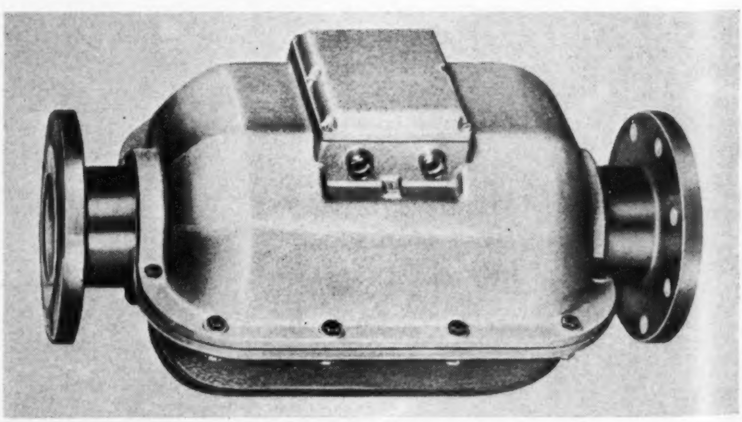
Air-cooled condensers

The use of air-cooled condensers has increased rapidly during the last few years. Such condensers have been used successfully in many branches of industry such as power stations with capacities up to 75 MW. Air-cooled water re-cooling plants have also been supplied to steelworks and to oil refineries where high condensation temperatures are used. The two German research reactors at Jülich, MERLIN and DIDO, with capacities of 10 MW and 5 MW, have also been equipped with air-cooled water re-cooling plants which have been developed by Gea-Luftkühlergesellschaft mbH., Bochum.

The use of air cooling is particularly recommended for solving various process engineering problems because there is no risk of contaminating products by cooling water. Mixed-air condensers have therefore been widely employed for all media that tend to block pipes such as fatty alcohols, fatty acids, naphthalene, etc.

Due to their thermal advantages and their small space requirements, column head condensers are becoming increasingly popular.





Magnetic flow measurement transmitter: left, *for rated bore of up to 25 mm.;* right, *for rated bore of over 40 mm.*

Conrad Naber electric heating furnace

Electric furnaces

Newly designed electric multi-purpose furnaces are exhibited by Conrad Naber. The housing of steel sheet is protected inside and outside by a double layer of synthetic enamel which improves the wear resistance. A very convenient design is the counterweight which is placed at the rear of the furnace where balancing movement saves effort and space, the calculated weight distribution making it easy to open and shut the door. The furnace is lined with refractory bricks which have a high mechanical strength and an extremely low coefficient of thermal conductivity. Hence there is a low current consumption and high furnace efficiency.

The furnaces are heated by means of spiral elements situated at the bottom and the sides of the furnace. A novel feature is the special tubes which carry the spirals and which prolong the working life of the element. The elements radiate freely into firing chamber, reducing temperature loss to a minimum. Thus a working temperature of up to 1,150°C. can be obtained. Cover plates are made of high thermal conductivity silicon carbide.

Glass plant

Highlight of the Q.V.F. Ltd. exhibit will be the 40-ft. glass distillation column towering over their pavilion. The column, 18 in. diam., is part of a distillation unit which visitors will see working.

Among other examples of plant on show in the pavilion are a reaction unit with a new type of immersion cooler, an absorption column with liquid circulated by a glass pump of the latest design and examples of glass overhead plant for use with glass-lined steel vessels.

Nuclear measuring instruments

A new series of nuclear measuring instruments based on a combination system which makes due allowance for the ever stricter requirements of measuring techniques is being exhibited by Frieseke & Hoepfner GmbH.

While a compact design is the ideal approach as far as standard instruments are concerned, the characteristic feature of the new series is that each functional unit has been assigned its own plug-in unit. This offers the advantage that a large number of combinations for a variety of measuring projects can be constructed from a limited number of plug-in units. The same series-produced plug-in units can be used as building blocks, starting from simple instruments to very intricate combinations for special measuring applications.

From the standard series of these measuring instruments the equipment for the gaseous-phase measurement of radioactive carbon and tritium is of particular interest for radiochemistry, an equipment which gives a yield of 50 to 55% for tritium and 70 to 80% for radioactive carbon.

Thermometers and pyrometers

A range of electrical thermometers and pyrometers are being exhibited by Pyro-Werk GmbH.

For the measurement of temperatures in molten metals there is the immersion pyrometer *Gispo*. An easily replaceable thermocouple, formed as a protected or bare metal thermocouple, is placed in an extension shaft. It carries the sector-shaped indicator with its 80-mm.-long scale and pointer arresting device. The temperature can be read in 10 to 15 sec. after immersion in the molten metal, so that even with corrosive materials the thermocouple will have a fairly long life.

To determine the temperature of surfaces of different kinds 17 different designs of surface pyrometers are made. For use in the works, a manual instrument with an 80-mm. scale is provided. It is made either in one piece with the surface feeler or can be connected separately with connecting lead and plug connection. A built-in automatic cold junction compensation makes the measurement independent of the room temperature.

The surface - contact pyrometer equipment consists of a surface tracer and a measuring instrument. The surface tracer contains a thermocouple in the form of a disc, band or needle. The following points are to be observed when measuring surface temperatures of any kind: Each heat-sensitive unit being in contact with the surface to be measured withdraws a certain quantity of heat from this surface and will, therefore, tend to lower its temperature. It is imperative that the contact between the tip and surface is intimate so that no resistance exists to the flow of heat from the surface to the thermocouple. Therefore, the mass of the thermocouple must also be small so that it will attain the surface temperature within a few seconds.

Hygrometer

For continuous measurement of temperature and relative humidity, Adolf Thiess are exhibiting a hygroscope with a LiCl measuring element. This hygroscope operates in conjunction with recording equipment. In this way it is possible to measure atmospheric humidity at dewpoints ranging from –30°C. to 130°C. In conjunction with a temperature element it is then possible to convert this to relative humidity. The measuring system is said to be highly accurate and to function accurately even when there are considerable variations in humidity. The apparatus can be used in plant or pipelines working under pressures of up to 15 atm.

Mass spectrometer

A range of mass spectrometers and gas chromatographs are exhibited by Atlas-Werke A.G., Bremen. The mass spectrometer CH 4 is a universal apparatus which is suitable for routine quantitative analyses of complex mixtures as well as for determination of isotope frequency in gaseous liquid and solid samples. It can, in fact, be used for all purposes for which a mass spectrometer is normally used. Its construction permits alterations in construction of apparatus without undue difficulties.

The accuracy that can be attained by quantitative analysis of gaseous and liquid sample probes is up to 0.3 mol%. The built-in membrane micromanometer ensures the correct sampling of probes and reliable control of analytical results. With a mass programme selector, up to 10 different

mass numbers can be selected. High-boiling substances as, for instance, solid hydrocarbons are admitted into the mass spectrometer through a heatable inlet system.

With the determination of isotope frequency for tracer analysis, an accuracy of up to 0.01% can be obtained. A double gas inlet and a fast switch enables a rapid comparison with the standard probe.

Centrifugal pumps

Pumps and compressors exhibited by Siemen & Hinsch GmbH. are known under the trade name *Sihi*. A development in the range of pumps has led to the self-priming lateral channel pumps and liquid ring gas pumps operating as vacuum pumps and compressors for oil-free gases. These pumps are based on the principle of the rotating liquid ring.

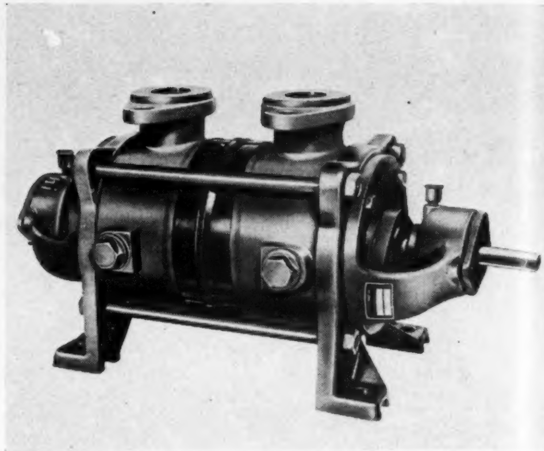
The range also comprises centrifugal pumps and a combination centrifugal and lateral channel pump. The newly developed standardised pump series has an improved hydraulic system as well as interchangeability of all parts. For the chemical industry self-priming vertical container pumps have been designed which can be attached, by means of a standard flange, on to a container platform. This series covers a range of delivery capacities up to 133 gal./min.

A large range of liquid ring gas pumps for use as compressors and vacuum pumps will also be exhibited. These pumps are used for compressing various industrial gases, for the deaeration of vacuum plants, for vacuum drying and for the separation of gases from liquids.

Glassed-steel plant

The use of glassed-steel equipment in the European chemical industry has increased during the last few years. Pfaudler Werke A.G. is exhibiting a range of glassed-steel reactors for which the heat-transfer coefficient can now be obtained by experimental methods.

The agitation of glassed-steel anchor agitators has also been studied and widely used methods for calculating agitation have been adopted. A new series of drives from 0.3 to 80 h.p. is now available with torque measurements ranging from 2 to 480 r.p.m. for agitating vessels with a capacity from 2.5 to 30,000 l. VS drives have been primarily developed for Pfaudler reactors and are therefore equipped with corrosion - resistant seals for operation over a wide temperature range.



'Sihi' reciprocating pump

Titanium plant

Whilst titanium is still one of the most expensive materials of construction for chemical plant, its increasing use in the chemical industry, particularly in processes involving high reaction rates and oxidising reagents with free chlorine ions, is evidence of its importance. Fried. Krupp Maschinenfabriken is exhibiting a range of titanium used in the manufacture of process equipment, such as *Tikrutan* RT 15 and RT 18. RT 15 is employed wherever a certain degree of elasticity to allow for appreciable deformations is required, and RT 18 where high strength is desired.

Titanium resists the attack of a great number of corrosive chemicals such as chlorine, chlorites, hypochlorite solutions, nitric acid, chromic acid, sulphides and organic liquids and it has a remarkable resistance to stress - corrosion cracking. Fried. Krupp have supplied titanium for many large process plants.

Graphite plant

Powell Duffryn Carbon Products Ltd. will be exhibiting a series of graphite heat exchangers with heat-transfer area ranging from 10 sq. ft. up to 200 sq. ft. and also cartridge condensers from 4 up to 90 sq. ft. In addition there will be two vertical spindle centrifugal pumps made of graphite for pumping corrosive fluids. One of these is a 4-in.-diam. pump with an impeller speed of 1,500 r.p.m.; the other is 8 in. diam. with an impeller speed of 3,000 r.p.m.

Graphite bursting discs are also shown with a test rig operated by compressed air. During the exhibition several disc sizes will be exploded; various discs will be constantly flexing under pressure.

Electronic instrumentation

The main consideration in selection of exhibits to represent George Kent Ltd. have been practical examples of the latest development in measuring techniques. Operation of exhibits under simulated working conditions will ensure realism.

Electronic instruments include examples of Mark 3 *Multelec* strip-chart recorder-indicator for measurement of temperature, current, millivolts, conductivity and flow (by electromagnetic method), etc.

The electronic section also features representative items from the new Kent *Transdata* system of electronic instrumentation.

Vacuum pumps

The exhibits of Edwards Hochvakuum GmbH., Frankfurt, will include a wide range of *Speedivac* vacuum equipment manufactured by Edwards High Vacuum Ltd., Crawley. Of particular interest to the chemical engineer will be the vacuum pumping equipment which includes vapour booster pumps, mechanical booster pumps and a redesigned range of mercury vapour diffusion pumps manufactured entirely in stainless steel. Among the accessories on display will be a range of stainless-steel quarter-swing butterfly valves which are available in sizes up to 6 in. internal diameter.

Engineers with an interest in the pharmaceutical industry will find of particular interest the new shelf freeze dryers in which the complete freeze-drying process, from initial freezing to the final capping of a product, is carried out under vacuum.

Among other equipment on display are ultra-high vacuum pumping systems and coating units which have

complete facilities for bake out to high temperature and which can achieve pressures below 10^{-9} torr.

Centrifuges

Sharples Chemische Einrichtungen GmbH. have increased their display to include three new machines in their range of centrifuges.

The Sharples *Gravitrol* DH-1000 self-cleaning separator brings completely automatic operation to the single-stage purification of land and marine fuel oils in the 2 tons/hr. range. This machine complements the well-known DH-2 and DH-3 machines, and can also be applied to lubricating oil purification.

Two of the recently introduced ranges of Sharples *Super-Screen* centrifuges will be displayed, one of which will be seen working with a P-600 *Super-D-Canter* centrifuge on the stand.

An extension to this range, to be exhibited, will be the Sharples vertical P-600 centrifuge. Designed to fit into pilot plants and small production units, this machine offers continuous solid/liquid separation under pressure, and a foretaste of exciting new developments in centrifugal engineering.

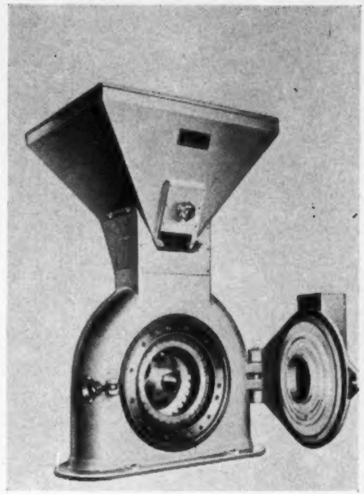
Fabricated titanium

Marston Excelsior Ltd., an I.C.I. subsidiary company, are showing examples of fabricated titanium for chemical plant. These include tanks, pumps, standard heating coils and tubular heat exchangers. A variable-pitch industrial fan with reinforced plastic blades for process cooling, aluminium secondary surface heat exchangers for low-temperature gas separation and bursting discs are also included. Fabricated zirconium reactor components and an aluminium-plate-type fuel element are examples of work for nuclear engineering.

Grinding in air vortex

In a grinding mill chamber the turbo (acting like a fan) sucks in a considerable quantity of both air and material to be ground. The flow of air and material is directed towards the centre of the rotating turbo where a certain amount of turbulence is generated. The turbo-mills exhibited by Hermann Bauermeister GmbH. are designed for grinding soft to medium-hard products. Final reduction in the air vortex inside the milling chamber is mainly done by self-friction and self-impact of particulate materials. The sieve-ring holds back over-size particles until they have been completely reduced in size.

Optimum efficiency of this turbo-mill can only be attained by completely utilising the air vortex produced in the mill. This ensures the highest degree of particle fineness, highest production, low power consumption and minimum plant wear. The plant should also be equipped with a well-dimensioned sacking hopper—for settling air turbulence—and filter bags. Material ratio and an efficient vortex are indispensable for obtaining correct air.



'Bauermeister' universal turbo-mill

Standard turbo-mills have a solenoid feeder and hopper. The mills can also be equipped with an additional mechanical feeding device driven directly through the mill shaft by a separate motor.

Insulation

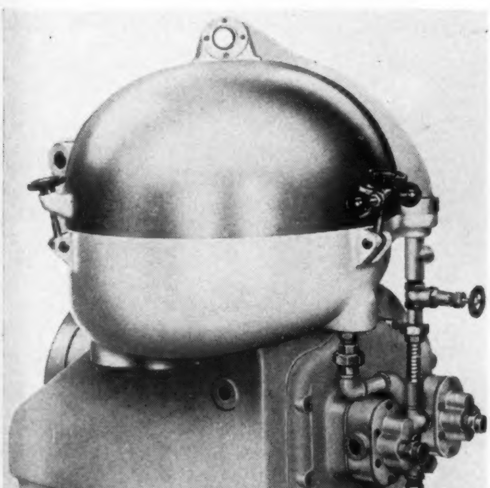
Johns-Manville International Corp. will be exhibiting in association with the following European companies: Lehmann & Voss, Oscar Gossler, Schneider & Co. and Vulcascot.

Two main types of products will be featured—*Celite* and insulation. In the former category are diatomaceous filter aids and mineral fillers, perlite products, *Calflo* synthetic calcium silicates used in cryogenics and as pigment extenders and chromatography support materials.

Insulation will cover every type of insulation the company now market in Europe together with a range of packings and sealing compounds.

Sheet filters

From the range of equipment made by John C. Carlson Ltd. to be exhibited there will be on show, for the first time, a 60-cm. sheet filter. Simplicity is said to increase the operating efficiency and facilitate cleaning. All contact parts such as filter plates, connections, etc., are manufactured in stainless steel. The filter plates are available in two designs, the first with corrugated insert and the second with expanded metal insert, each of them ensuring that the liquid



Sharples 'Gravitrol' DH-1000 centrifuge

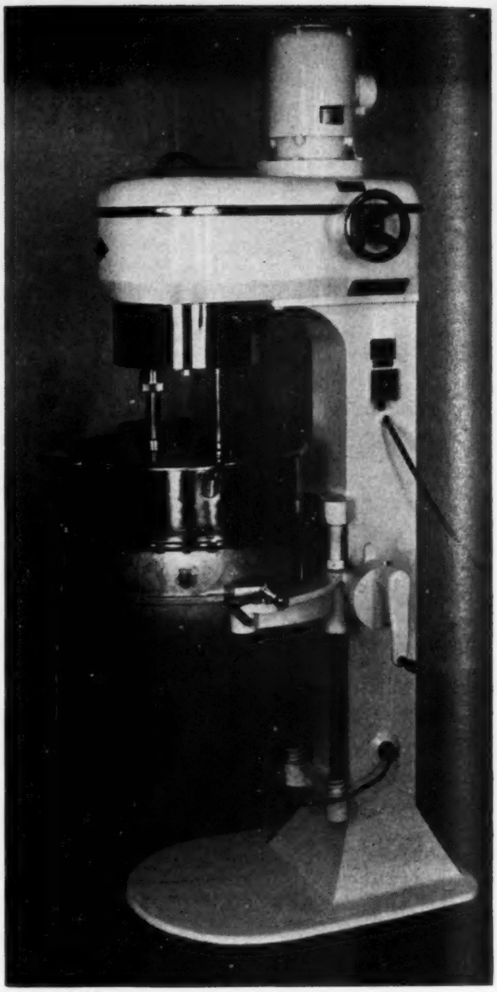
is distributed in a most efficient and effective manner.

Carlson sheet filters of 40-cm. and 20-cm. sizes, a range of laboratory filters as well as a representative selection of the company's filter sheets will complete the display. For mildly corrosive conditions sheet filters are available with filter plates of *Nolac*—an anodised aluminium magnesium alloy which does not require a protective lacquering. They are also supplied in a light-metal aluminium alloy, lacquered.

Mixing equipment

F. Herbst & Co. are exhibiting their range of planetary mixers, which have found application where kneading, homogenisation and intensive mixing are required.

Elektro-Rapid has variable planetary gears and a counter-currently operating wiper blade. The mixing bowl can be easily raised or lowered and is supplied either with a double-wall or with water bath. The advantage of this design is that, due to the variable planetary gears, the mixer can be used for many differing operations ranging from kneading of dough-like materials to the mixing of powders. Its main applications are in the cosmetic, pharmaceutical, paint, lime and food industries.



' Electro-Rapid ' 9 mixer with tilting bowl and lid

Distillation plant

The chemical engineering division of the A.P.V. Co. Ltd. will present details of some of the projects completed by them during recent years. Amongst these will be a number of benzole refineries and alcohol distilleries. Also shown will be plant which has been supplied to the chemical and pharmaceutical industries.

Among process plants designed by the company are batch and continuous refineries for crude benzole, tar acids, tar bases and naphthalene-rich oils; plant for the separation of aromatics from certain cracked naphtha sidestreams; distillation plant for the separation and/or concentration of certain hydrocarbon fractions, chemicals, alcohols, etc., alcohol distilleries, solvent recovery and extraction plants.

High-pressure plant

Dr. Thiedig & Co. K.G. is exhibiting a range of plant for high-pressure processes, including piston compressors, with effective capacity 30 cu.m./hr. and operating pressure up to 2,000 atm., and piston pumps for gases and liquids with operating pressures up to 3,000 atm. There are also autocalves with electric resistance heating or circulating oil heating with automatic temperature control. Their capacity is up to 30 l. and operating pressure up to 2,000 atm. with a maximum operating temperature of 700°C. In addition there is a range of magnetic mixers and control instruments for chemical processes.

Production of phthalic anhydride

A number of improvements in the gas-phase oxidation of naphthalene to phthalic anhydride has given excellent results in industrial plants.

It is well known that the naphthalene used for oxidation is not pure. Hence tarry and solid constituents tend to contaminate the catalyst giving rise to choking and an increase in back-pressure after a certain period of operation. This defect is eliminated by a special design and method of operating the evaporator.

The reaction of the naphthalene vapour with air is carried out in a tubular converter which is maintained at a constant temperature by means of an internal salt bath with forced circulation. A special design ensures that each individual contact tube can be cooled externally with an equal quantity of the circulating salt. The heat liberated in the reaction is led away and recovered in the form of high-pressure steam.

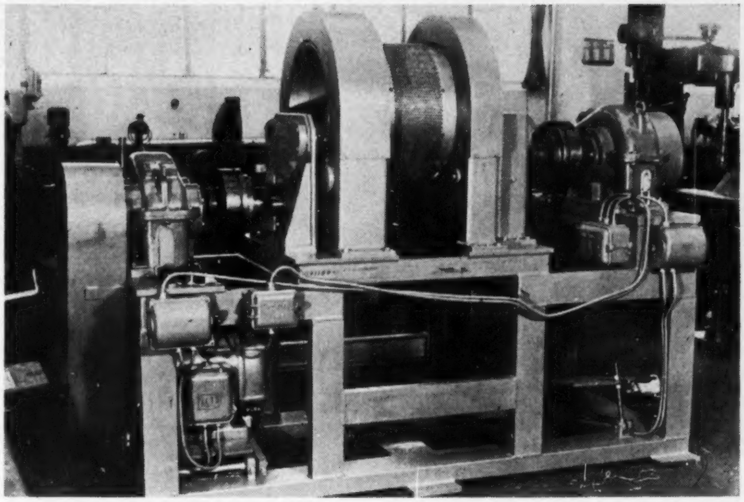
The phthalic anhydride is separated in the solid form from the reaction gases in specially designed finned tube separators. When one separator has been filled, the stream is switched over to a second unit. The former is strongly heated with the steam from the heat recovery unit and the condensed phthalic anhydride melted off.

The large sublimation chambers formerly used can be improved by using plant which has been adapted to suit the reaction conditions. Instead of having to deal with solid phthalic anhydride for processing and distillation, it is now possible to process the product continuously in pipelines by a simple pumping operation.

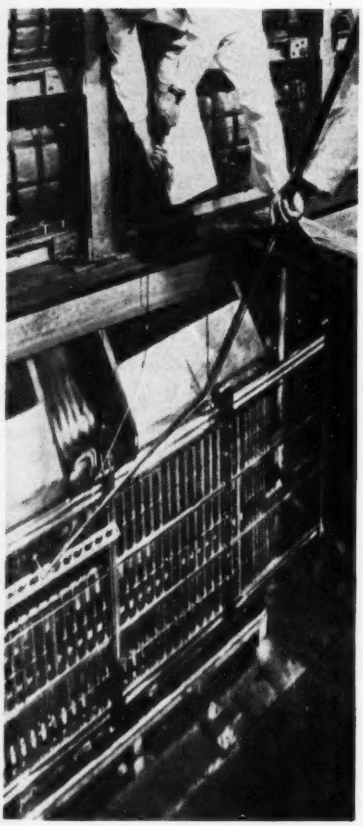
The Chemiebau Co. Dr. A. Zieren GmbH., Cologne, has already built several such plants under licence from Chemische Fabrik von Heyden A.G., and others are being planned or are under construction.

Uranium production

The United Kingdom Atomic Energy Authority will show several aspects of their work. One section of their stand will illustrate the Authority's achievement in bringing to a full industrial-production scale the manufacture of natural uranium fuel elements for the British nuclear power programme and for stations exported by U.K. firms. Fuel reprocessing after its use in the reactors will be described in detail.



Rotary granulator for fertilisers. Hourly throughput, 5 to 7 tons



View of the world's first commercial irradiation source at the Westminster Carpet Co., New South Wales. The source contains 650,000 c. cobalt-60 and is used for irradiating bales of goat hair to destroy anthrax

Working models of the latest prototype equipment designed for the chemical processing of uranium ores and for separating plutonium-bearing solutions from those containing fission products will be on view. Much of this equipment can be used to improve yields or purities in ordinary chemical plants.

The radioisotope section will provide information on industrial irradiation plants, showing how they are used for the sterilisation of medical and other supplies. These use radioactive cobalt which is available in quantity from the Authority's Radiochemical Centre at Amersham. The stand will emphasise the wide range of 'labelled compounds' which the Authority can supply and give examples of uses of newly-developed bremsstrahlung sources and of tritium or its compounds.

Granulating machines

There are many inherent advantages in granulated materials, such as reduction in volume, decrease in drying time, dust prevention and ease of packaging. Alexanderwerk A.G., Remscheid, are exhibiting various granulating machines which work on the following principle. The pretreated material is fed into the machine by means of a rotary table feeder or proportioning worm and then enters the orbit of the cylinders. These counter-rotate with different speeds. Due to this speed differential, friction is created and this rubs the material into the perforations, the granules leaving the cylinder at the open front. In many cases one of the granulating cylinders is replaced by one without perforations for the purpose of generating a higher pressure. One or two scrapers keep the inside of the cylinder walls clean.

These granulators can be used to convert fertilisers, dyestuffs, ceramics, waxes, powdered metals and salts into free-flowing bodies. These can then be used as intermediates in the manufacture of tablets where fine-grained materials with a percentage of fines is required or where, for further processing, finely powdered materials have to be converted into granules or rods which must be completely free of fines.

Centrifuges, filters and plant

The Dorr-Oliver exhibit will consist of two stands. One stand will be devoted to a display of machines from a wide range of equipment and the other to complete plants sold to various industries over the world.

Another development which will be displayed is a vacuum drum filter in polyester fibreglass construction useful for corrosive service. Also in the range of filtration equipment, a pressure horizontal filter will be exhibited.

There will be a working model of a *FluoSolids* (fluidised bed) plant, which is used for roasting, calcining and drying and offers accurate temperature control, low fuel consumption and low space requirements.

There will also be a model of a plant for oil-separation from refinery waste water.

Production of Low-tritium Deuterium

By J. S. Drury,* B.S., R. H. Guymon,* B.S.(Chem.Eng.), and E. F. Joseph,* B.S.(Chem.Eng.)

This article is based on work performed for the U.S. Atomic Energy Commission to obtain high-purity deuterium. A small, electrolytic facility for separating tritium from deuterium was designed and operated, and more than 400 kg. of deuterium oxide and about 70,000 N.T.P. litres of deuterium gas were purified. The average ratio of tritium to deuterium in the product was 6×10^{-16}. The purified deuterium can then be used in bubble-chamber experiments.

THE development of the bubble chamber[1] as a tool in the study of high-energy nuclear reactions created an interest in tritium-depleted deuterium for use as a liquid target. Ordinarily, the tritium content of hydrogenous materials is too small to be of concern, even to nuclear physicists. In high-purity deuterium, however, the concentration of tritium is relatively great because the isotopic enrichment process used to concentrate deuterium also concentrates tritium. Thus, in 99.8% deuterium there is usually at least one atom of tritium for each 10^{13} or 10^{14} atoms of deuterium. This concentration of tritium is sufficient to cause an intolerably high spurious activity in certain types of bubble chamber experiments. For this reason, the isotope separation group of the Oak Ridge National Laboratory was asked to prepare deuterium and deuterium oxide with a T/D ratio of 2×10^{-15} or less. A yield of deuterium and deuterium oxide equivalent to 100 l. of heavy water was required.

Separation methods

Two methods of separating deuterium from tritium received serious consideration—electrolysis of deuterium oxide and distillation of liquid deuterium. The distillation method was recommended by the relatively large vapour pressure differences estimated[2] for D_2 and DT, by the ease of obtaining multi-stage separations in distillation equipment, and by the high production rate which could be obtained in very small apparatus. Disadvantages of the method were the relatively high capital costs associated with the low-temperature equipment and the uncertainties of the technology involved. On the other hand, the electrolytic process was expected to have a separation factor larger than that for the distillation method. Furthermore, if only a few electrolytic cells were used, the required capital investment would be relatively low. The technology involved in this method was well known. The major disadvantages of the method were:

(1) A lower production rate than the distillation method if only a limited number of electrolytic cells were used, and

(2) with only a few cells, batch operation would have to be employed and a relatively long delay would occur before any product would be available for use.

The electrolytic method was chosen largely because the availability of surplus electrical equipment allowed a lower estimate of cost for this method than for the distillation method.

Design considerations

In the electrolysis of heavy water, separation of deuterium from tritium is achieved because D_2O is converted to D_2 more rapidly than DTO is converted to DT. Thus tritium concentrates in the residue of the electrolyte while the gas phase is enriched in deuterium. If the gas-phase deuterium is repeatedly converted to water and partially re-electrolysed, any desired purification from tritium can be obtained. For large quantities of product, this purification may be performed most economically on a continuous basis with a series of cells and hydrogen recombiners. However, only a modest quantity of product was required and, to minimise the capital investment, it was decided to use a batch operation in which the processed material was recycled through a few pieces of equipment until sufficient isotopic separation was achieved.

The instantaneous separation factor for the fractionation of tritium and deuterium by electrolysis of heavy water is given by:

$$\alpha_o = \frac{(T/D)\ \text{liquid}}{(T/D)\ \text{gas}} \quad \dots\dots\dots\dots (1)$$

where (T/D) gas is the ratio of tritium to deuterium in the gas which is formed at a given instant and (T/D) liquid is the same ratio in the electrolyte. The value of α_o has been measured for certain operating conditions[3, 4] and may be estimated from measurements made in hydrogen-tritium and hydrogen-deuterium systems.[5, 6] From these sources it was estimated that an α_o of about 2 might be obtained under the planned operating conditions. As in all Rayleigh-type separations, however, the isotopic fractionation observed in a batch electrolysis is less than that represented by the instantaneous factor, α_o. The isotopic separation which results from the fractional electrolysis of a given volume of water is given by:

$$\alpha_{eff} = \frac{\theta}{1 - (1 - \theta)^{\beta}} \quad \dots\dots\dots (2)$$

where α_{eff} is the T/D ratio in the original solution divided by the aver-

*Chemistry Division, Oak Ridge National Laboratory, Tennessee, U.S.

age T/D ratio in the gas produced during the electrolysis, θ is the 'cut' or fraction of the charge which is electrolysed and β is the reciprocal of the instantaneous separation factor, α_0.

It can be seen from equation (2) that isotopic fractionation decreases with increasing cut. It would seem advantageous, therefore, to electrolyse only a small portion of each charge. However, if this is done, the yield decreases very rapidly and it is necessary to greatly increase the volume of liquid which must be processed to yield a given quantity of product. The dependence of the yield on the fraction of the charge which is electrolysed in a series of runs is shown in equation (3).

$$\frac{V_p}{V_e} = \frac{\theta^{n-1} - \theta^n}{1 - \theta^n} \quad \ldots\ldots\ldots\ldots (3)$$

where V_e is the volume of liquid electrolysed, V_p is the volume of product, θ is the fraction of the charge electrolysed in each run and n is the number of electrolyses required to yield water of the required purity. If a large cut is made, the yield from a single electrolysis is high but the isotopic purity is low. There is, therefore, an optimum cut which minimises the time and energy required to produce a given yield of product. In the present case, the optimum cut was found to be approximately 0.8. The effective separation factor for this cut was estimated to be 1.45. Using this separation factor, it was calculated that a total of 11,000 l. of heavy water would have to be electrolysed in a series of 15 consecutive batch runs to produce 100 l. of product having a T/D ratio of 2×10^{-15}. Further calculation showed that, with 24-hr./day operation, this volume of water could be processed in three 1,400-amp. cells in about one year.

The electrolyte

Sodium or potassium hydroxide is usually chosen as the electrolyte when water is electrolysed. In the present instance it was not feasible to use these hydrogen-containing compounds because of isotopic contamination. Therefore, a non-hydrogen-containing electrolyte was sought which could be thoroughly dried before and after use, and which would be completely stable under the conditions of electrolysis. Potassium carbonate met these conditions and was selected for use.

In multi-stage electrolyses of heavy water, the stoichiometric mixture of deuterium and oxygen resulting from one electrolysis must be recombined to serve as feed for subsequent runs. This recombination may be accomplished catalytically or by combustion. The latter method was chosen for this project because of its simplicity and certainty of operation. Use of the combustion method required some arrangement of containing the flame to prevent it from travelling backward through the gas stream to the cells. Steam chambers and water traps which are frequently employed for this purpose were not feasible because of contamination of the process stream with hydrogen or tritium. Sand traps were considered too unreliable for use. It was decided, therefore, to feed the electrolytic gas into the burner through an orifice-type flame arrestor.

Since a portion of the final product was required as deuterium gas, equipment had to be provided to convert heavy water to deuterium. An electrolytic cell, in which the anode and cathode were separated by an asbestos-cloth diaphragm, was designed for this operation.

Under the plan of operation which has been described, 20% of the heavy water originally charged to each cell would remain as a concentrated potassium carbonate 'waste' solution at the end of each run. Calculations showed that the T/D ratio of the water in this solution would be about three times greater than the T/D ratio of the gas produced in the same run. However, after several consecutive batch electrolyses, the waste solution would contain less tritium than the heavy water with which the series of runs was initiated. The water in the residue from the latter electrolyses, therefore, would constitute a valuable product of intermediate purity.

It was planned that the heavy water should be recovered from the concentrated potassium carbonate solution by a two-stage distillation. To shorten the time required for processing, it was decided that the used potassium carbonate should be discarded after each run and that freshly dried salt should be used to make up each fresh charge of electrolyte.

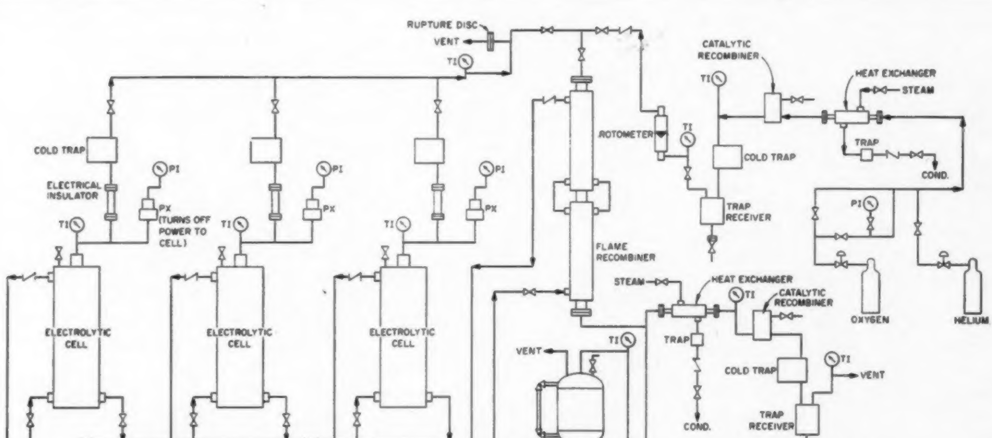


Fig. 1. Isotopic separation unit

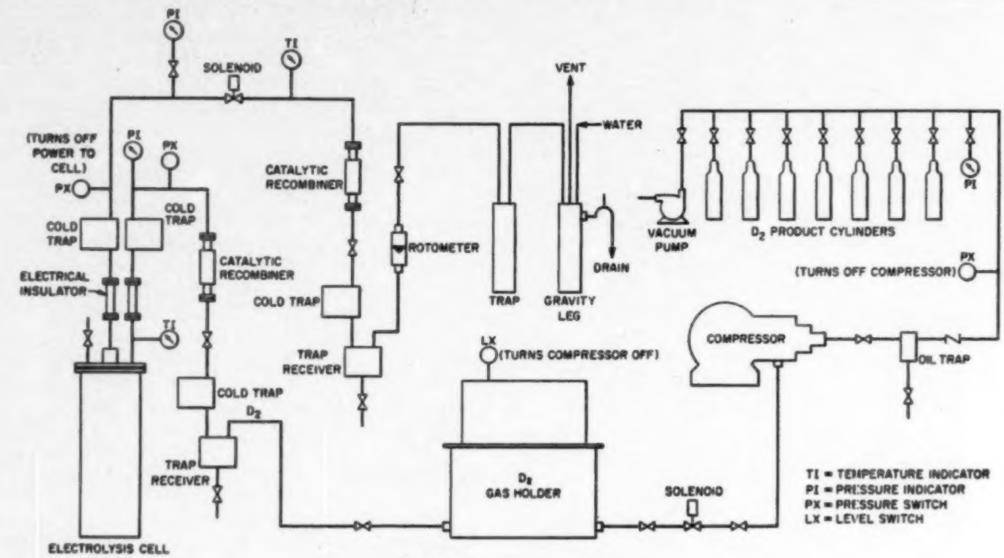


Fig. 2. Gas conversion system

Since deuterium is costly, precautions were needed to prevent its loss or contamination during each step of the processing. All vents were designed with catalytic recombiners and dry ice traps to prevent the escape of deuterium or deuterium oxide to the atmosphere. Similar precautions were taken to prevent ordinary hydrogen from entering the system in the tank oxygen which was added to the recombiner during the combustion step. Finally, appropriate provisions were made to cover the heavy water, which is hygroscopic, with a blanket of dry, inert gas to prevent contamination with atmospheric moisture.

Plant description

The facility for the production of low-tritium deuterium consisted of three separate units—the isotopic enrichment system, the gas conversion system and the waste recovery system. A schematic sketch of the isotopic separation unit is shown in Fig. 1. The principal components of this unit were three electrolytic cells, each with its own rectifier, auto-transformer and control panel; a flame recombiner; and a product receiver. The cells were constructed of 12-in., Schedule 40, mild-steel pipe and were designed to withstand occasional explosions of the electrolytic gas which they contained. The casing of each cell served as the cathode. The anode consisted of a 19-in. section of nickel pipe 11.75 in. outside diameter. The entire length of the anode fitted into an annular recess in the bottom of the cell with a 0.5-in. clearance on either side from the cathode. Each cell was jacketed.

Tap water was used for temperature control. Schedule 80 pipe fittings were attached to the top and bottom of each cell for use in loading and draining electrolyte. No partitions were used between the electrodes; deuterium and oxygen gas passed from each cell through a single opening in the top of the cell. A thermometer was placed in the gas stream at the exit point. Immediately above each cell a cold trap, operating just above the freezing point of deuterium oxide, stripped out essentially all of the heavy water vapour carried by the gas stream.[7] (Isotopic dilution of the product with entrained electrolyte was minimised by using the upper portion of the electrolysis cell as an entrainment separator.)

The gas from each cell was fed into a manifold through which it entered the flame recombiner. Attached to this manifold was a rupture disc which was designed to fail at 125 p.s.i.g. to relieve excess pressure in the system in the event of an explosion. The recombiner unit was a 70-in.-long, 3-in.-i.d. section of Schedule 40 stainless-steel pipe. It was mounted in a vertical position and was surrounded by an upper and lower cooling jacket. The electrolytic gas entered at the top of the burner through a nozzle consisting of five orifices, each of which was 0.75 in. long and 0.040 in. in diameter. The cross-sectional area of the orifice was chosen so that the linear velocity of the gas stream would exceed the velocity of the flame in hydrogen, and thus prevent combustion of the electrolytic gas in the cells.

Near the end of the nozzle a spark plug extended through the side of the flame recombiner to ignite the gas. The spark plug was fired continuously by an ignition transformer which supplied a high-frequency 6,000-V pulse. A spark monitoring device was incorporated into this circuit to signal any failure of the spark-generating equipment. In the recombiner wall, at right-angles to the spark plug, there was a *Pyrex* viewing port through which the recombining flame could be observed. A 35-gal. stainless-steel receiving tank was placed beneath the recombiner and was connected to the latter by means of a vented dip leg which prevented explosive gases from accumulating above the liquid level of the receiver. The vent line was equipped with a catalytic hydrogen-oxygen recombiner and a dry-ice trap to prevent loss of any unburned deuterium in the gas stream. As an additional precaution against the loss of deuterium, provision was made for adding additional oxygen to the electrolytic gas before it was burned. This oxygen supply line was equipped with a pressure regulator and rotometer for flow control, and a catalytic recombiner and dry-ice trap to remove any normal hydrogen which might be present in the commercial-grade oxygen which was used.

Differential-pressure pneumatic cells were used to indicate the pressure in each electrolytic cell during operation. The use of ordinary pressure gauges was not feasible in a system in which explosions of electrolytic gas were expected to occur. Pressure-activated switches sounded an alarm and de-energised the rectifiers when the pressure in the cells fell below or exceeded certain preset values.

Electrical power was supplied to each electrolysis cell by individual copper oxide rectifiers which were capable of delivering a maximum rectified current of 1,400 amp. at 7.5 V.

Gas conversion system

A schematic sketch of the gas conversion system is shown in Fig. 2. The principal components of this system were an electrolytic cell with its power supply and control panel, a dry-type low-pressure gas holder and a gas compressor. The gasification cell was similar in external dimensions and construction to the three isotopic enrichment cells. However, it differed from these internally. The anode was a 21.5-in.-long, 10-in.-i.d. cylinder constructed of 0.25-in. nickel plate. Both the top and the bottom of the anode were closed to minimise the volume of electrolyte required for operation. In the space between the electrodes, a 16-gauge mild-steel shield extended from the top of the cell to the top of the anode, dividing the upper portion of the cell into two gas-tight areas.

A woven asbestos-cloth diaphragm was attached to the lower edge of the shield and extended to the bottom of the cell. An outlet was provided above the cathode compartment to withdraw the deuterium gas. Oxygen was removed from the cell through an opening in the anode assembly. Cold traps were placed immediately above the cell in each gas stream to strip heavy water from the exit gases. A hydrogen-oxygen catalytic recombiner and a dry-ice trap removed any remaining water or gaseous impurity from either stream. In the oxygen line there was also a thermometer, a pressure gauge, a solenoid valve which closed in the event of a power failure, a needle valve and rotometer for flow control, a constant-head gravity leg and an atmospheric vent.

The dried deuterium gas passed directly to a 30-cu.ft. dry-type gas holder. This gas holder was equipped with a plunger section which was connected to the tank by means of a gas-tight neoprene skirt. The construction of the gas holder was such that it could be completely evacuated to avoid contaminating the deuterium gas with air. The gas holder was equipped with limit switches which could:

(1) Energise the compressor when the gas holder was filled to the normal operating level;
(2) De-energise the compressor when the gas holder was empty; and
(3) De-energise the rectifier which supplied power to the electrolytic cell if, for any reason, the gas holder was filled to its maximum capacity.

A horizontal, four-stage tandem gas compressor pumped the gas from the gas holder into individual cylinders having a capacity of 192 cu. ft. at 2,000 p.s.i. Loss of deuterium through the stuffing box of the compressor was avoided by the use of a normally closed solenoid valve in the line between the gas holder and the compressor. This solenoid valve was connected electrically to the compressor motor so that it remained open only when the compressor was in operation. The gas from the compressor was discharged into a manifold to which eight size 1A gas cylinders could be attached at one time.

By simultaneously filling sufficient cylinders to accommodate all the deuterium produced during the electrolysis of a given batch of heavy water, the composition of the gas in each cylinder was maintained at an average purity. If the cylinders were filled one at a time, rather than simultaneously, the gas in the first few would have a greater purity, with respect to tritium, than was needed, and the gas in the last few would have been too impure to be considered a final product. A high-pressure safety-limit switch was attached to the gas manifold to turn off automatically the compressor motor when the pressure in the manifold reached a predetermined value. Also attached to the manifold was a vacuum pump which was used to evacuate air from the filling apparatus prior to the introduction of deuterium.

The waste recovery system consisted of a small, two-pot metal still and one all-glass multi-plate distillation unit. The pots of the metal still were 29-in.-long, 4-in.-o.d. cylinders, flanged on top and wrapped over their

Table 1. Typical operating conditions

	Enrichment system	*Gasification system*
Cell voltage	3.5	3.8
Cell current (amp.)	1,000	200 to 250
Cell pressure (p.s.i.g.)	3.0	2.3
Volume of water electrolysed per hour (litres)	1	0.065 to 0.080
Temperature of gas leaving cell (°C.)	27	27
Fraction of charge electrolysed	0.8	0.5
Electrolyte charged per cell (kg.)	25	62.5
Initial composition of electrolyte (wt.%):		
K_2CO_3	10	11
D_2O	90	89
Cold trap temperature (°C.):		
Stripping	5	5
Final	−80	−80

Table 2. Typical production data

Enriching system	
Initial D_2O feed (kg.)	294.3
Feed purity, $T/D \times 10^{-14}$	1.6
D_2O product from initial charge (kg.)	63.9
Product purity, $T/D \times 10^{-16}$	4.3
Number of consecutive electrolyses to obtain product	7
Average 'cut' per electrolysis	0.8
Average effective separation factor (α_{eff})	1.8
Average instantaneous separation factor (α_o)	2.8
Average current efficiency	98.3
Gasification system	
Rate of deuterium production, N.T.P. l./hr.	90 to 115
Average product purity:	
$T/D \times 10^{-16}$	5.7
Atom % deuterium	99.0
Atom % hydrogen	1.0
Volume % oxygen	0.08
Volume % nitrogen	0.10
Average current efficiency (%)	98.0

entire length with insulated resistance heating wire capable of operating at 250°C. One pot was constructed from 316 stainless steel; the other, which was part of some existing equipment, was nickel. The operating temperatures of the two pots were governed by individual temperature controllers. Steam from one or both of the still pots was condensed in a small shell and tube condenser and flowed by gravity to a 22-l., round-bottom glass flask. This flask was equipped with an electrical heating mantle, a short, helices-packed glass exchange column, a water-cooled glass condenser and a 13-gal. polyethylene receiving vessel. The temperature of the heating mantle was controlled manually by means of a potentiometer.

Plant performance

The performance of the completed plant exceeded expectations. After an initial shake-down period, both the enriching and gasification equipment performed well. The enriching cells were operated 168 hr. a week. During one-half of this time, the equipment was completely unattended. Two favourable circumstances were encountered which had not been anticipated. The effective separation factor was found to be about 20% greater than was estimated, and a supply of raw material was found which contained somewhat less than the predicted concentration of tritium. As a consequence of these circumstances, it was possible to achieve 100 l. of product having a T/D ratio of 6×10^{-16} in less time than was scheduled originally for a product having a T/D ratio of 2×10^{-15}. The operation of the gasification equipment proved to be a more delicate task than the operation of the enriching cells; nevertheless, the gasification system was made to perform completely automatically throughout the course of a batch electrolysis. About 400 kg. of D_2O and 70,000 N.T.P. l. of deuterium having a T/D ratio of 6×10^{-16} were prepared. Typical operating and production data are shown in Tables 1 and 2.

The progress of the purification process was followed by analysing deuterium gas prepared from product and residue water samples by the method of Dubbs.[8] The tritium content in these samples was analysed by Dr. F. T. Hagemann and associates at the Argonne National Laboratory. Analyses for hydrogen, deuterium, nitrogen and oxygen were made with a conventional 6-in., 60° sector mass spectrometer.

Acknowledgments

Many individuals contributed to the success of this project. The authors wish to thank Dr. J. A. McLaren, O.R.N.L., for suggestions concerning cell design and Messrs. B. Kuperstock, Y-12, and A. A. Palko, O.R.N.L., for valuable design and operating suggestions. The co-operation of Dr. F. T. Hagemann and associates, A.N.L., in performing many tritium analyses was appreciated especially. Thanks are due to Dr. W. M. Jackson and Messrs. P. E. Miller and R. T. Atkins, O.R.N.L., for co-operative and attentive operation of the equipment, and to Mr. D. A. Lee for preparation of the gaseous samples.

REFERENCES

[1] D. A. Glaser and D. C. Rahm, *Phys. Rev.*, 1955, **97,** 474-479.
[2] A. S. Friedman, D. White and H. L. Johnston, *J. Chem. Phys.*, 1951, **19,** 126-127.
[3] P. W. Selwood *et al.*, *J.A.C.S.*, 1935, **57,** 780.
[4] S. Kaufman and W. F. Libby, *Phys. Rev.*, 1954, **93,** 1337-1344.
[5] J. Hariuchi and T. Nakamura, *J. Chem. Phys.*, 1950, **18,** 395-396.
[6] M. L. Eidinoff, *J.A.C.S.*, 1947, **69,** 2507-2509.
[7] A. E. Bainbridge, NS-1, New Zealand, 1959.
[8] C. A. Dubbs, *Anal. Chem.*, 1953, **25,** 828.

Oil tankers

What are the new trends in oil tanker design and what is the economic outlook for the tanker industry? In the May issue of **Petroleum** several articles are appearing on this subject. Other articles in this issue are: Effect of Tank Coating on Tanker Efficiency, by P. G. Neal. L.P.G. Strides Ahead. France Plans Expansion of Petrochemicals, by J. Bertin-Roulleau.

The following other articles appearing in our associate journals may be of interest to readers of CPE.

Manufacturing Chemist—Temperature Measurement and Control, by A. Linford. Small-scale Manufacturing Equipment—3: Tabletting, by J. E. Carless. Annual Survey on Expansion in the British Pharmaceutical Industry.

Corrosion Technology—Report on First International Congress on Metallic Corrosion. Epoxy Resins in Solvent-free Coatings, by P. A. Dunn.

World Crops — Agriculture and Economic Growth, by E. A. Attwood.

Food Manufacture—Special feature on Screening and Sieving. Annual reviews on Canning and Freezing, Jams and Preserves.

Fibres and Plastics—Chemistry and Uses of Polyurethane Foams. Low-temperature Radiant Heat Drying—2, by H. L. Smith.

Automation Progress — X-ray Methods of Automatic Analysis, by D. C. Munro. Trends in Process Control, by D. G. Taylor. Hydraulic Servomechanisms—2, by N. A. Shute and D. E. Turnbull.

Paint Manufacture—Equipment for Paint Spraying, by G. E. Court. Manufacture and Application of Fatty Acids, by G. A. Allan. Advanced Paint Chemistry—16, by P. M. Fisk.

Dairy Engineering — Review on Crate Handling Equipment. Special feature on Vending Machines.

Specimen copies of these journals and subscription forms are available from the Circulation Manager, Leonard Hill House, Eden Street, London, N.W.1.

Water-pollution research

Steps are to be taken to improve international co-operation in scientific research on water pollution.

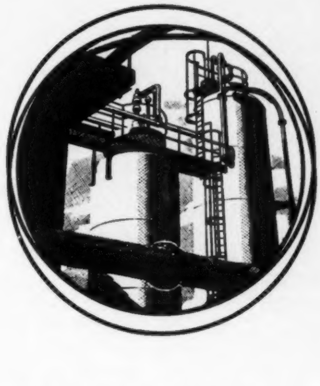
This was decided at the first international meeting on the technical aspects of scientific research into water pollution.

The meeting, which was organised by the Applied Research Committee of the O.E.E.C., was held at the Chateau de la Muette, Paris, and included representatives of various international bodies and directors of research laboratories in O.E.E.C. member and associated countries.

The meeting recommended the setting up of working parties for co-operative research on methods for determining the degree of pollution of water courses and estuaries.

Standardisation of the sampling methods and chemical, biological and other forms of analysis, studies on water pollution due to detergents and preliminary study on the mixed treatment of household and industrial effluents.

Materials of Construction for Chemical Plant



CAST IRON

By H. H. Collins,* F.R.I.C., A.C.T.(Birm.)

The thirteenth article in our series on materials of construction for chemical plant is on cast iron. Previous articles have dealt with PVC, lead, nickel, stainless steels, graphite, polyolefines, copper, timber, platinum, titanium, aluminium and reinforced plastics. Although cast iron is not so universally used as formerly, it still has unique and specialised properties for use in chemical plant construction. Generally it is used where its cost to life ratio is superior to that of any other material.

WHEN iron ore is smelted with coke a crude form of cast iron called pig iron is produced. Castings are made by remelting pig iron. When a high degree of analytical control is required, castings are produced by melting refined iron, that is, pig iron whose composition has been homogenised and adjusted by a remelting process. The simplicity of the transition of iron ore to iron castings is partly responsible for the cheapness of iron castings and this has always been an important factor governing the use of cast iron.

Cast iron is primarily an alloy of iron and carbon containing various other elements derived from the original ore, the amounts of these elements being subsequently augmented or diminished according to the properties required of the alloy. The fact that cast iron contains a large percentage of carbon leads to an important property—its ability to give a sharp impression of the mould into which the molten metal is cast. This ability arises from the fact that, during cooling of the melt, graphite is deposited as flakes which grow throughout the solidification and cooling process, and the difference in density between graphite and iron produces an overall expansion of the metal during solidification; as a result the casting reproduces the contours of the mould.

Because of its good founding properties and cheapness, cast iron has always been an important constructional material and one of the lessons of the study of the use of cast iron in the chemical industry today is that these two reasons still predominate in maintaining its importance in the face of competition from metals and materials of much shorter history.

Structure and composition

The structure of an iron casting depends on its composition and the rate at which it is cooled from the molten state—and hence its section size—and, in those castings which are heat treated, on the nature of subsequent heat treatment.

Almost all the castings used in the chemical industry consist of a pearlitic matrix in which graphite flakes, whose dimensions depend largely on the section of the casting, are randomly dispersed (Fig. 1).

Irons have recently been developed in which the form of the graphite developed on solidification is roughly spheroidal (Fig. 2). The absence of graphite flakes in these 'nodular' graphite irons causes the iron to be much stronger than a flake graphite iron, while the deposition of the graphite during solidification ensures

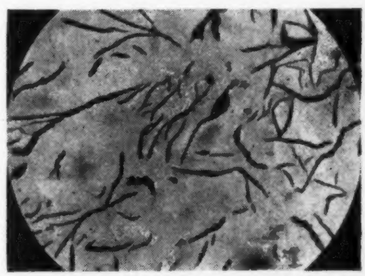


Fig. 1. Typical microstructure of a heavy chemical casting. Coarse flake graphite in a pearlitic matrix. Etched in 4% 'Picral' (×60)

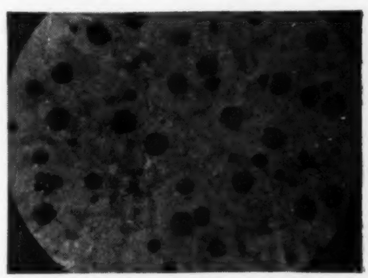


Fig. 2. Pearlitic nodular graphite iron. Etched in 4% 'Picral' (× 100)

**The British Cast Iron Research Association.*

that the iron still has good founding properties. If such a nodular graphite iron is heat treated to give a ferritic structure, then an appreciable degree of ductility is conferred on the iron.

The composition of an iron depends very much upon the duty that it will be required to perform. Since the most abundant iron ores in the United Kingdom have high phosphorus contents, the cheapest pig irons also have high phosphorus contents. A high phosphorus content makes the production of sound castings more difficult and also increases the brittleness of the iron. For most castings used as components of chemical plant a low phosphorus content is mandatory. In fact, probably the only extensive use of high phosphorus irons in the chemical industry is for centrifugally cast pipes. Here the shortcomings of the high phosphorus iron are reduced by the production method used. The centrifugal casting process—in which a fixed quantity of molten metal is poured into a horizontal cylindrical metal or sand mould rotating axially at a very high speed — produces uniformly sound and dense castings. With metal spun pipes, the fine structure resulting from the rapid cooling of the metal in the metal mould produces a very finely distributed phosphide eutectic network with a consequently decreased effect upon the ductility of the iron. With sand spun pipes the centrifugal force acting on the slowly cooling metal in the sand mould squeezes the liquid phosphide eutectic from the solidifying iron towards the interior of the pipe so that the bulk of the metal is relatively low in phosphorus while the inner rim is phosphide-rich.

The carbon content of an iron determines the amount of graphite present in its structure. The amount of carbon dissolved in the iron, and therefore the amount of free graphite present, is affected by the presence of other elements, notably silicon and phosphorus. The phosphorus content of most irons for chemical duties should be low, but the proportions of carbon and silicon in a casting vary with the size of the section to be cast. It is difficult to give hard and fast rules, but contents of 3.0 to 3.5% carbon are normal with silicon contents ranging between 1 and 2.5%. Too high a carbon-plus-silicon content leads to a coarse-grained weak iron which probably has a slightly poorer resistance to corrosion than a lower-carbon finer-grained iron.

Sulphur is normally present in cast iron as manganese sulphide. Its presence in amounts greater than about 0.1% can lead to segregation and unsoundness and it is not usually allowed to exceed this level. Many chemical castings are deliberately made by remelting refined irons of low sulphur content, but the pick-up of sulphur which usually occurs on melting an iron in the cupola necessitates desulphurising the iron in the ladle before casting. This is normally done by tapping the iron from the furnace into a ladle containing some soda ash. The fluid sulphur-bearing slag formed is then thickened by the addition of lime chippings and skimmed off. However, the nature of the slag is such that its separation from the metal is by no means easy, although, by taking pains, manufacturers of chemical plant overcome the difficulty successfully. This practice is sometimes required even when a relatively low-sulphur iron is being produced in the cupola, because the addition of soda lime is thought to have some grain-refining effect.

In addition to the elements naturally occurring in pig irons, irons for chemical castings sometimes contain nickel and chromium, deliberately added to improve particular properties.

Some typical analyses of chemical castings are quoted in Table 1.

Table I

	Centrifugally cast pipe	*Heavy chemical castings*	*Heat-resisting cast irons*	*Nodular graphite irons*
	%	%	%	%
T.C.	3.2 to 3.4	3.0 to 3.5	3.0 to 3.4	3.3 to 3.9
Si	2.5 to 2.8	1.0 to 2.0	1.1 to 1.5	1.6 to 2.5
Mn	0.3 to 0.4	0.5 to 0.7	0.5 to 0.8	0.4
S	0.1	0.08 max.	0.15 max.	<0.01
P	1.1 to 1.3	0.15 max.	0.2 max.	<0.1
Ni	—	Up to 3.0	—	0 to 1.5
Cr	—	—	0.3 to 0.6	—
Mg	—	—	—	0.04 to 0.10

Mechanical properties

Cast iron is specified in a series of grades according to the tensile strength of a bar cast to a diameter of 1.2 in. (British Standard 1452 : 1956). For ordinary flake irons the tensile strength normally ranges between 10 and 20 tons/sq.in., and for a given section size the tensile strength of an iron is largely conditioned by the amount of graphite present in its structure. Since this depends on the amount of combined or dissolved carbon present in the matrix and this is modified by the silicon and phosphorus contents of the metal, the relationship is strictly between tensile strength and carbon equivalent value, where the carbon equivalent value is the sum of the total carbon content and one-third of the combined silicon and phosphorus contents:

$$\text{C.E.} = \text{T.C.} + \frac{\text{Si} + \text{P}}{3}$$

Other elements, notably nickel, also modify the amount of combined or dissolved carbon present in an iron, but to a much smaller extent. Typical relationships for carbon equivalent value and tensile strength are shown in Fig. 3. Under maximum tensile load, cast iron fractures with no appreciable deformation.

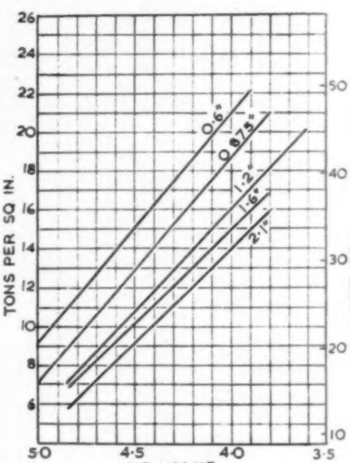


Fig. 3. Relationship between carbon equivalent value and tensile strength for varying sizes of cast bars

The compression strength of cast iron is about three to four times its tensile strength. Thus, for the same safety factor, the maximum compressive load for an iron is as high as that for a steel of three to four times its tensile strength.

Most cast irons of the type and analysis used in the chemical industry will have a Brinell hardness number between 180 and 240, but the precise hardness of a casting is very dependent on the composition and structure of the iron.

Cast iron is a brittle material at all

temperatures. This implies that, when a cast iron component is overloaded to the point of failure, it is liable to fail catastrophically and without any warning deformation first becoming apparent.

The limiting fatigue stress for cast iron under conditions of alternating load is between one-third and one-half of its tensile strength.

Because of the difference in graphite distribution, nodular graphite iron has different mechanical properties from flake graphite iron and the two cannot be correlated with each other. The tensile strength of nodular graphite iron is much higher than that of flake graphite iron and annealed ferritic nodular graphite iron is much more ductile. The hardness of the as-cast nodular graphite irons is higher than that of the flake graphite irons, but that of the annealed nodular graphite irons is lower. The impact resistance at room temperature of the pearlitic nodular graphite iron is higher than that of flake graphite irons although the alloy remains essentially brittle. With nodular graphite irons, as with steels, there is a transition from a ductile to a brittle mode of failure by impact at low operating temperatures. The temperature of the transition depends on the composition and microstructure of the iron. Pearlitic nodular graphite irons have a relatively high transition temperature and normally fail by brittle fracture, but ferritic nodular graphite irons have transition temperatures below room temperature so that they may generally be regarded as ductile. Typical properties for nodular graphite irons are given in Table 2, together with a wide range of flake graphite iron properties for comparison.

Table 2

	Pearlitic flake graphite	*Pearlitic nodular graphite*	*Ferritic nodular graphite*
Ultimate tensile strength, tons/sq.in	10 to 20	40 to 48	24 to 32
Elongation, %	<1	1 to 5	15 to 30
Brinell hardness No.	180 to 240	240 to 290	130 to 170
Fatigue limit (unnotched), tons/sq.in.	4 to 10	16 to 20	10 to 14
Modulus of elasticity, p.s.i. ..	11 to 21 × 10⁶	24 to 26 × 10⁶	22 to 24 × 10⁶

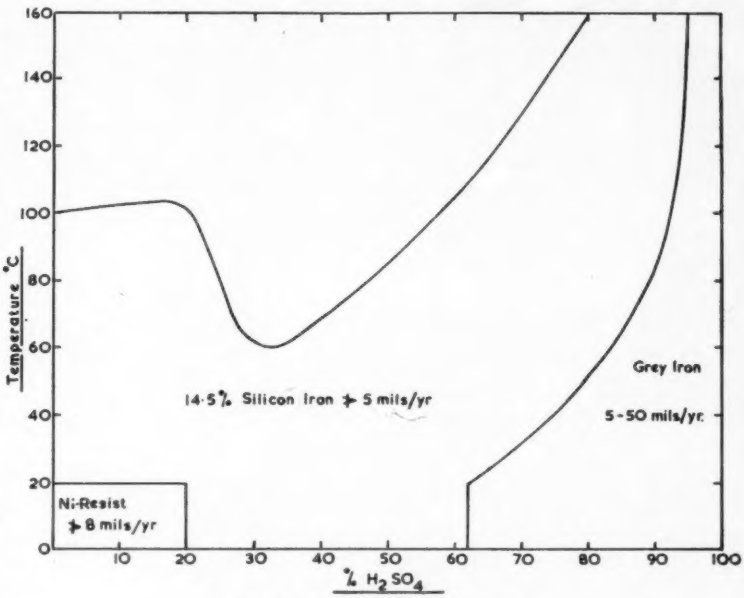


Fig. 4. Corrosion of iron by sulphuric acid

General corrosion properties

Cast iron is a relatively reactive alloy and its principal advantages in the chemical industry generally stem from properties other than its chemical inertness.

The presence of graphite flakes in the iron naturally has an effect upon the corrosion of cast iron. They probably act as centres for hydrogen evolution and behave cathodically to the matrix, thus stimulating corrosion. Under conditions which do not allow the precipitation of the corrosion product close to the metal, iron is leached away from the casting to leave a corrosion residue composed of graphite flakes and other incorrodible microconstituents, particularly the phosphide, and plugged with amorphous debris and rust. According to the permeability of this graphitic corrosion residue—which depends on the structure of the iron and the conditions of corrosion—it may either promote or reduce the corrosion rate. Over a sufficient time interval it probably reduces it. The development of this residue gives rise to the so-called graphitic corrosion of cast iron.

Generally, cast iron has no useful resistance to acids or acid solutions. An acid solution stronger than 0.001 N may be expected to corrode cast iron at a rate not less than 0.01 in. p.a. Sulphuric acid of more than 65% strength, however, is not corrosive to cast iron at room temperature and it becomes even less corrosive at higher concentrations, so that acid of 95% strength is readily handled by cast-iron equipment even at temperatures approaching its boiling point (Fig. 4). This phenomenon is due to the limited solubility of ferrous sulphate in strong solutions of sulphuric acid, with the result that corrosion of the iron is accompanied by the development of a stifling film of ferrous sulphate on the corroding surface.

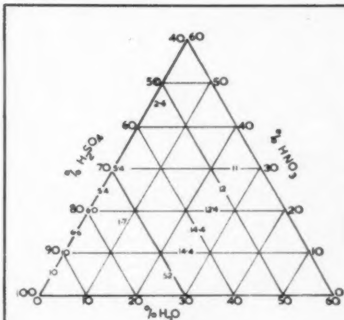


Fig. 5. Corrosion rates (mils/yr.) for cast iron in contact with mixed acids (H_2SO_4, HNO_3, H_2O)

Mixed nitric and sulphuric acids such as are used for nitrations are also not greatly corrosive to cast iron, presumably for the same reason. Fig. 5 shows some figures derived from various authors for this system.

Although fuming nitric acid can passivate steel, the phenomenon seems to be too uncertain to allow cast iron to be used with this acid at any concentration. Oleum does not attack cast iron, but two accounts have been published which attribute cracking of iron castings to intergranular reaction between the iron and the oleum. In fact, cast iron is often used with oleum and it is possible that the reported cases of cracking may not be directly due to such a reaction.

Resistance to alkalis

Cast iron is not corroded by alkali solutions of less than 30% concentration at any temperature, and solutions of up to 70% do not attack it at rates greater than 0.008 in. p.a., providing the temperature does not exceed 80°C. Hotter and more concentrated solutions attack iron at increasingly rapid rates (up to 0.10 in. p.a.) (Fig. 6).

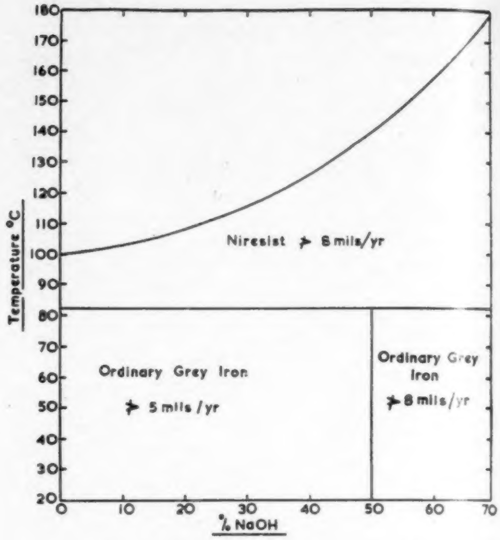


Fig. 6. Corrosion of iron by sodium hydroxide

The behaviour of cast iron towards salt solutions depends on the chemistry of the particular solution and the degree of aeration encountered. Salts which hydrolyse to form an acid solution, such as aluminium sulphate or calcium chloride, are corrosive, while those acid salts which are also oxidising agents or whose solutions are well aerated are particularly aggressive. On the other hand, salts which give neutral or alkaline solutions are generally not corrosive to cast iron, although their corrosivity may be greatly increased if the solutions are well aerated.

It seems probable that the atmospheric corrosion of cast iron is generally similar to the atmospheric corrosion of steel. However, because of the much greater thickness of castings, it is rarely important from the point of view of metal preservation.

The corrosion of buried metals is a very complex topic. The corrosion rate of a large metal structure, for example a pipeline, buried in the ground depends rather on the development and activity of large-scale electrochemical corrosion cells than on the intrinsic corrosivity of the metal. Cast iron has, in fact, an excellent record of resistance to buried corrosion, rates of attack often not exceeding 0.001 to 0.005 in. p.a.

Fig. 8. Cast-iron caustic soda pot and cover. Weight 23 cwts.

Highly alloyed cast irons

There are three classes of highly alloyed irons. These are iron-carbon alloys containing large amounts of silicon, chromium and nickel respectively. Their basic properties and uses are summarised in Table 3.

High-silicon iron is essentially an acid-resisting iron. It has an excellent resistance to sulphuric acid of all concentrations, to strong nitric acid solutions, and to most organic acids. Hydrochloric acid attacks silicon iron much less than any other ferrous alloy, but the rate of attack is still high (Fig. 7). Since this iron depends on the formation of an impermeable film of silica for its corrosion resistance, it has no useful resistance either to hydrofluoric acid solutions or to caustic alkalis. The iron has the disadvantage of being very hard and brittle.

Table 3. Highly alloyed cast irons

Name	Analysis %	Structure	Mechanical properties			Remarks
			Ultimate tensile strength, %	*Elongation on 2 in.,* %	*Brinell hardness No.*	
High silicon iron	T.C., 0.4 to 0.7 Si, 14*	Fine flake graphite in silico-ferrite matrix	9	Nil	450	A very brittle iron with outstanding acid resistance
High-chromium iron	T.C., 0.8 to 1.5 Cr, 25 to 35	Complex carbides in chromium-ferrite matrix	30	Nil	320	A very hard and difficultly machinable iron. High resistance to corrosion by oxidising solutions. High resistance to abrasion. It is highly resistant to oxidation at elevated temperatures and its high critical temperature and great carbide stability make it virtually free from growth at less than 1,050°C.
Ni-resist	T.C., 3.0 Ni, 22† Cr, 2	Medium flake graphite in nickel-austenite matrix containing some chromium carbides; or Nodular graphite in nickel-austenite matrix containing some chromium carbides	11 to 16 24 to 30	3 8 to 20	130 to 160 140 to 180	Generally better resistance to corrosion by neutral or alkaline media than unalloyed iron. It has a good resistance to oxidation and its very low critical temperature and absence of metastable carbides make it virtually free from growth at less than 950°C. The addition of 5% silicon (*Nicrosilal*) improves the oxidation resistance

* For increased resistance to hydrochloric acid, the silicon content is increased to 18% or 3% Mo is added.

† The nickel content is often reduced to 14% and 7% copper is substituted. This alloy has generally similar properties to those quoted.

High-chromium iron is essentially a heat-resisting iron, with excellent heat-resistance properties. Its corrosion resistance depends on the presence of a film of chromium oxides, so that it is only exceptionally resistant to acid or neutral solutions which possess oxidising characteristics. It is particularly suitable for handling solutions of nitric acid of less than 70% strength. The iron is hard and has an excellent resistance to abrasion, which often makes it suitable for pump castings handling abrasive slurries, even when the chemical nature of the solution may be relatively corrosive.

The high-nickel irons have much better heat resistance than unalloyed cast irons. The increased nickel content also confers a measure of resistance to cold dilute acids (Figs. 4 and 7) and an excellent resistance to hot concentrated alkali solutions (Fig. 6). It is particularly useful for handling solutions of salts which are moderately corrosive to cast iron, for example sea-water. The high nickel content makes the alloy more noble than unalloyed iron or steel. This has the advantage that the graphite flakes present in the alloy do not have the same stimulating effect upon the corrosion rate that they may have in unalloyed irons.

Applications in industry

The chemical industry may be said to have begun in England in the latter years of the 18th century. Its beginning coincided roughly with the beginning of a cast-iron founding industry largely independent of the blast furnaces and antedated the beginning of the steel industry by about 100 years. The basic materials of construction then available were bricks, stone, pottery, wood and cast iron. As the chemical industry grew, the use of iron castings became more important. At least one foundry in the Widnes district was initially built to meet the growing demand of the young chemical industry, and the tradition of service to the chemical industry persists to this day.

Until recently, and particularly until the technique of welding had pro-

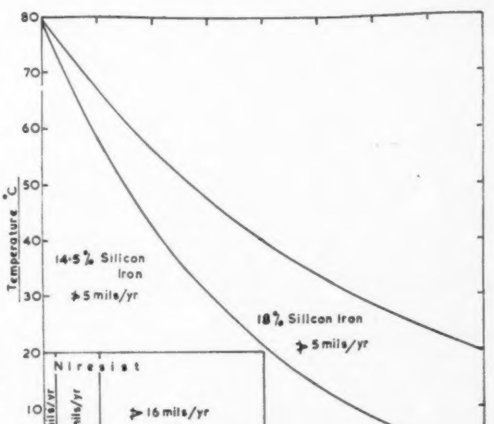


Fig. 7. Corrosion of high silicon iron by hydrochloric acid

gressed sufficiently to allow the construction of reliable fabricated steel components, cast iron was used predominantly in most aspects of the chemical industry because it had no rival. It is now being slowly supplanted, mainly by steel, for various components and duties, although it is still very extensively used. Since it has special and unique properties there is no foreseeable likelihood of it becoming obsolete as a material of construction. For many pieces of plant there is at present no obvious economic alternative. Foundries report a continuing steady demand by the chemical industry for castings. The total tonnage of castings produced in 1959 for the needs of the chemical and gas industries was 34,000 tons.

Broadly speaking, cast iron is used whenever its cost to life ratio is better than that of any competitor and when considerations of safety, resistance to internal high pressures, or weight are not important. Generally in the chemical industry, grown accustomed over the years to handling heavy components, the mere weight of a casting is no serious drawback except, perhaps, in the case of overhead pipelines. The disadvantages of cast iron from the point of view of safety are essentially those which limit its use to low-pressure applications. Cast iron is a brittle material. If a casting is overloaded to the point of failure, it fails catastrophically and, possibly, explosively. Obviously this risk cannot be countenanced when the component is handling dangerous chemicals or where personnel may be injured by flying fragments. On the other hand, in the low-pressure field, the cost to life ratio for cast iron is often extremely good compared with other metals, and its long history of use means that the engineer is completely conversant with all the good and bad characteristics of the material and need not depend on data derived from relatively short-term trials.

Cast iron is used to produce components whose complicated shape introduces fabricating difficulties; components to resist severe abrasion; components to resist the combined effect of abrasion and corrosion; components to resist corrosion by concentrated sulphuric acid solutions; components to handle very aggressive media under arduous operating conditions; components to resist corrosion by dilute alkali solutions; components to handle relatively innocuous chemicals; components to withstand elevated temperatures; general-duty, low-strength structural items; and components to act as radiological shields.

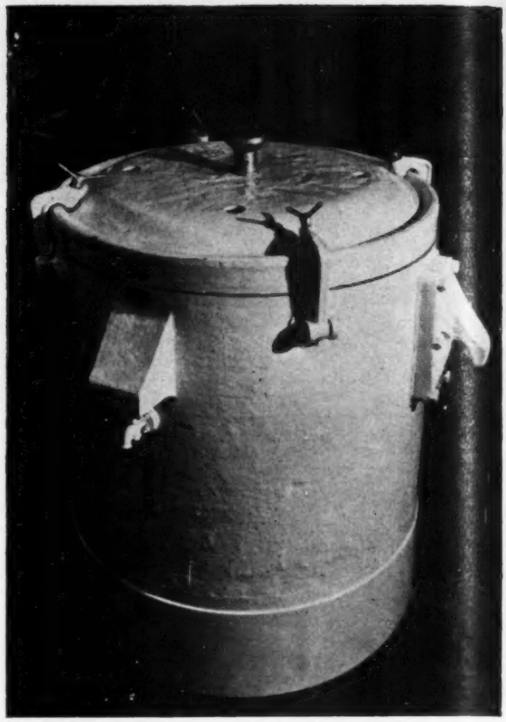


Fig. 9. One of a battery of five special cast-iron vessels on order for the U.K.A.E.A. The complete vessel weighs approximately 28 tons

Cast-iron pumps and valves are found throughout the chemical industry. These castings are also made in other more corrosion-resistant alloys, but cast iron predominates. Many large chemical castings of today are just as complicated as a pump impeller or volute and can be most readily made in cast iron. Film-drying drums and particularly the very large steam-heated cylinders used in the paper industry for drying, glazing and creping paper are also components which would be difficult to make in any way other than by casting.

Crushing and grinding machines are often provided with extremely hard alloyed or white cast-iron teeth and jaws. The arduous duty of the machines demands a wear-resistant metal rather than a hardened surface and their complicated nature would usually make machining expensive if not impossible.

When a corrosive slurry is to be handled, a thin-walled steel tube will have only a short life before penetration occurs, while it would be difficult to provide a coating, with the possible exception of soft rubber, which could adequately resist the abrasive component. If, as often happens, the slurry is also hot, the problem is even more difficult. Cast iron, however, is slightly more resistant to abrasion and no less resistant to corrosion than mild steel and, for approximately the same cost, the component walls will be two to three times as thick. Cast-iron pipe is therefore often used to withstand such conditions.

Generally, when a particularly aggressive chemical is to be handled under such arduous conditions, particularly of temperature, that no protecting coatings can be used, then cast iron is chosen; partly undoubtedly because of the relatively low cost of replacement, but partly because of the increased rigidity of the casting and especially its increased resistance to distortion at elevated temperatures. There is also a general belief in indus-

The material of construction for chemical plant which will be discussed in next month's issue of CHEMICAL & PROCESS ENGINEERING will be

MILD STEEL

try that cast iron has a better resistance to acutely corrosive conditions than steel, not solely because of its increased section thickness. An example of the use of cast iron under such very severe conditions is found in the cast-iron retorts used for the synthesis of carbon disulphide by the reaction between gaseous sulphur and charcoal at about 900°C. A typical life for such a retort is six months. Similarly difficult conditions are encountered by caustic soda and sodium bisulphate fusion pots which are always made in cast iron (Fig. 8).

Cast iron is not appreciably attacked by hot, dilute solutions of caustic alkalis and many items of chemical plant which are to handle such solutions are made from cast iron. Many components required to handle sulphuric acid at greater than 65% concentration are made from cast iron. These include the piping leading from the contact plant, acid coolers, acid reaction or concentration pots and oleum stills. Many items required to handle mixed acids are also made of cast iron.

Because of their other properties, castings are often used to handle relatively innocuous media. For example, dry chlorine gas is handled by cast-iron blowers because it is easier to produce them by casting than by fabrication. Many reaction kettles and vats are made from enamelled iron. The greater rigidity of a casting compared with a fabrication diminishes the chance of accidental impact causing flaking of the brittle coating and the increased section of the casting increases the life before penetration should the coating fail. There seems no good reason why the quality of enamel applied to a casting should be less chemically inert than that applied to a fabrication, but there is certainly a tendency at the moment to replace enamelled cast iron by the more expensive glassed steel.

This account would not be complete without referring to the use now made of cast iron for constructing radiological shields. An interesting example is the container for radioactive waste (Fig. 9) which is accepted for purchase only after exhaustive radiographic inspection.

It is typical of the attitude of many engineers today that cast iron was only thought of for this purpose after other more expensive materials had been rejected for practical, not economic, reasons. Cast iron is too often regarded as a cheap and second-rate substitute for other materials, rather than as a material, admittedly with limitations, but with unique and useful properties of its own.

It is being supplanted from its one-time unassailed position by other superior and more expensive materials, but in many situations it is still holding its own. In the ammonia-soda processes, for example, iron castings are still used to an overwhelming extent. This is because it is as much a unique constructional material as stainless steel or reinforced resin. To its technical advantages, however, is added the advantage of a low cost.

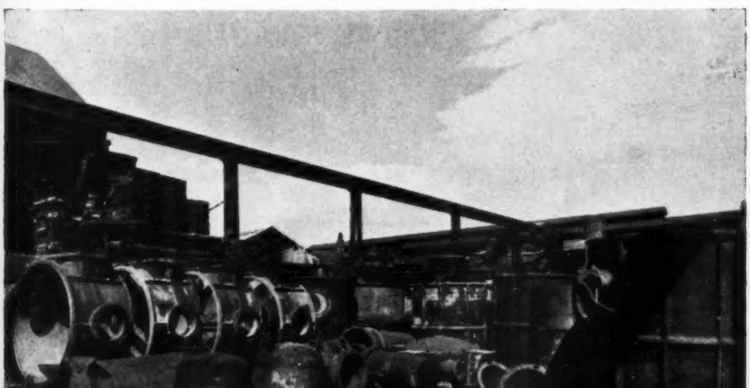


Fig. 10. Collection of heavy castings for chemical plant

INDUSTRIAL PUBLICATIONS

Lead applications. A publication designed to be of general interest to readers wishing to expand their knowledge of lead is available from the Lead Development Association. The leaflet discusses lead pigments for primer paints for iron and steel.

Solvents. A 44-page booklet that describes the use of organic chlorine compounds as solvents, extractants, fumigants, intermediates and special-purpose fluids is available from Union Carbide International Co. It contains comprehensive data on 13 organic chlorine compounds. Included are physical properties, cleaning formulations, toxicological properties, shipping, storage and handling information, test methods and selected literature references.

Heat exchangers. A publication of Alco Products Inc. contains a detailed technical article on the selection of materials for use in the manufacture of heat exchangers. It also contains an article on the world's largest water filtration plant, now under construction at Chicago, Illinois, and an article on a large, new, crude-oil pipe still which has been put into operation at Whiting, Indiana.

Properties of air. A critical survey of the existing state of knowledge of the physical properties of atmospheric air, giving practical working tables of correction factors, has been published by D.S.I.R. (price 2s. 6d.). Consideration has been given to likely ambient conditions in most laboratories and clinics throughout the world, and the range of the work has been planned accordingly. The book contains four-figure tables of correction factors for a pressure range of 600 to 850 mm. Hg, a temperature range of 10° to 40°C. and a humidity range of 0 to 100%.

Gland packings. A comprehensive reference book on the use of gland packings has been published by Crane Packings Ltd. There is a description how the correct gland packing can be selected for any combination of service conditions. An equipment code which is reproduced as a bookmark flap provides an at-a-glance reference to the equipment for which each gland packing is suitable. Alongside each gland packing there are code letters to complete the reference.

Nuclear Notes

Fusion research

A contract for co-operation on the promotion of experimental and theoretical research into controlled thermonuclear fusion has been concluded between Euratom and the Plasma Physics Institute (principal associate, Max-Planck-Gesellschaft), Garching.

The contract will cover an initial period of three years. The total cost of the project is estimated at DM. 30 million, 33% of which will be borne by Euratom and 67% by the Plasma Physics Institute. Once the laboratories now being built at Garching are completed, some 80 scientists and engineers will be employed there.

The Euratom Commission is already participating in fusion research through two contracts:

(1) With the French Commissariat à l'Energie Atomique (C.E.A.). Under the terms of this contract, 104 scientists are working at Fontenay-aux-Roses.

(2) With the Italian Comitato Nazionale per l'Energia Nucleare (C.N.E.N.). Some 60 scientists are employed at Frascati on research work under this contract.

Negotiations for the conclusion of another contract in this field with the Nuclear Research Centre at Juelich (Germany) are already under way.

NESTOR achieves criticality

A new 10-kW reactor, NESTOR, was put into operation for the first time at A.E.A., Winfrith, in March. Its purpose is to act as a source of neutrons for sub-critical assemblies of nuclear fuels and moderators.

The reactor core, control gear and instrumentation was designed and installed by the Hawker Siddeley Nuclear Power Co., who modified the design of their JASON reactor to enable up to five sub-critical assemblies to be driven simultaneously by the reactor. This concept represents a major advance in the use of a reactor as a neutron source.

The reactor is capable of operation at 10 kW (heat), giving a thermal neutron flux of 10^{11} neutrons/sq.cm./sec. in the centre of the core and of up to 10^{8} neutrons/sq.cm./sec. in the sub-assemblies. The thermal neutron flux for each sub-critical assembly can be varied by altering the reactor power level, by using neutron shutters or by rearranging the fuel loading in the annular core.

The nuclear fuel in NESTOR is an alloy of highly-enriched uranium and aluminium in the form of aluminium-clad plates arranged in an annulus around a graphite cylinder, and natural water is used both as coolant and moderator. The reactor is provided with control and safety rods, and additional control is possible by varying the water level. The experimental assemblies will be placed in 'caves' formed in the shielding at the sides and above the reactor. The whole shielding is arranged to be demountable so that the caves can be rebuilt to accommodate major changes in the requirements of the experimental programme.

The name NESTOR (neutron-source thermal reactor) was chosen because Nestor was one of the Argonauts led by Jason in the quest for the Golden Fleece.

The photograph shows Sir Ben Lockspeiser, chairman of the newly formed Nuclear Energy Standards Committee of the British Standards Institution, speaking as he opens the first meeting of the committee at British Standards House. On left of him is Mr. G. Weston, technical director, and on right is Mr. H. A. R. Binney, the director of the British Standards Institution

Bubble chamber conference

A conference was recently held at the Institute of Nuclear Science, Dubna, on advances in bubble chambers. Participants at the conference came from universities and research institutes of Bulgaria, Hungary, East Germany, China, Poland, Rumania, Czechoslovakia and the U.S.S.R.

Most of the discussions at the conference centred around methods of analysing experimental data obtained from bubble chambers. It was decided during the conference to circulate the millions of actual photographs taken in the Dubna bubble chamber to research institutes of countries who had participated at the conference.

Closing down

The research group of Hawker Siddeley Co. is to be disbanded. The company became interested in nuclear energy in 1954 and formed a small design group in 1956 with the

aim of specialising in marine reactors. It will be interesting to see what the company intends to do with JASON, which is probably the first privately-owned reactor to come on the second-hand market.

The one profitable manufacture which the company has developed for the nuclear industry is impermeable graphite. This graphite, used extensively by the Atomic Energy Authority, has a great potential future in chemical plant construction.

Uranium from Australia

The Australian Government has accepted a favourable tender for the mining of the newly discovered uranium orebody at Rum Jungle Creek South in the Northern Territory. The government has decided to continue operations at Rum Jungle by re-investing the profits earned under the existing contract. The reserves of uranium ore already established at Rum Jungle Creek South are greater than all other deposits of uranium which have been established. The ore can be treated at the existing treatment plant at Rum Jungle.

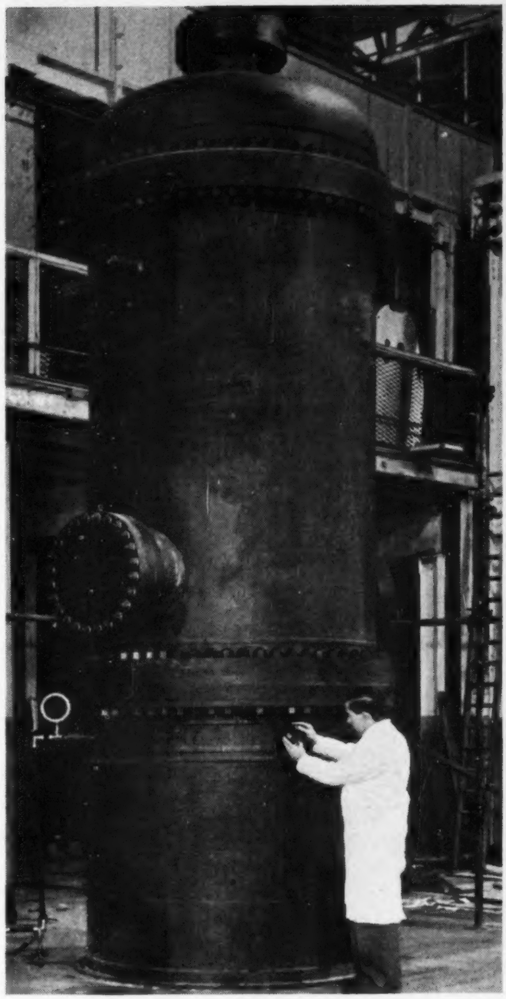
The market for uranium is likely to be uncertain for a period of years after the expiry early in 1963 of the existing Rum Jungle contract. However, Rum Jungle will produce uranium oxide for sale at competitive prices either for Australian requirements in the long term or for world markets.

Australia is proving to be one of the few countries with substantial deposits of uranium. It is necessary, therefore, to take the long-term view and conserve and develop the valuable natural resources of uranium which are owned by the Australian Government in the Rum Jungle area.

. . . to Turkey

The U.S. Atomic Energy Commission recently sent 2,500 kg. of natural uranium fuel to the Government of Turkey for a sub-critical assembly to be used for research purposes at the University of Ankara.

The cost of the fuel, approximately $100,000, will be paid from U.S. Mutual Security Funds as part of the 'Atoms for Peace Programme'. The sub-critical facility is being built for the physics department of the University of Ankara and will be used as a laboratory tool for training graduate and undergraduate students in reactor and neutron physics. On graduation, some of these students will be engaged in the programme for use of the research reactor which is now under construction in Istanbul.



PRESSURE VESSEL

This Class 1 pressure vessel is one of the latest fabrications for nuclear engineering work built in alloy steel by Fairey Engineering Ltd. It is 18 ft. high, weighs 9.2 tons, and is being installed at Fairey Engineering's headquarters at Heston, Middlesex, for functional tests on mechanical equipment to be used in the Trawsfynydd nuclear power station reactors. This station is being built by Atomic Power Constructions Ltd., the consortium of which Fairey Engineering is a member company.

Tests will be made inside the pressure vessel in an atmosphere of hot (400°C.) pressurised (290 p.s.i.) carbon dioxide which will simulate conditions inside a reactor. In this photograph the vessel is being subjected to an hydraulic pressure test.

How VERA operates

The major purpose of the new VERA reactor at the A.W.R.E., Aldermaston, which went critical for the first time late in February, is to gather information in an area where it has up to now been substantially lacking, *i.e.* that of medium-enrichment, of diluted and of slightly moderated fast reactor systems.

The reactor cell has walls 6-ft. thick and a ceiling 3-ft. thick. Around the cell are located the control room, the fuel element assembly room, laboratories, plant room for the ventilation system and filters and a laboratory to house a 600-kV accelerator, still under construction. This accelerator will be used to produce deuteron beams aimed at targets in sub-critical VERA cores which will yield bursts of neutrons in a series of kinetic experiments to measure reactivity increments and neutron lifetimes and to study neutron spectra with varying core compositions.

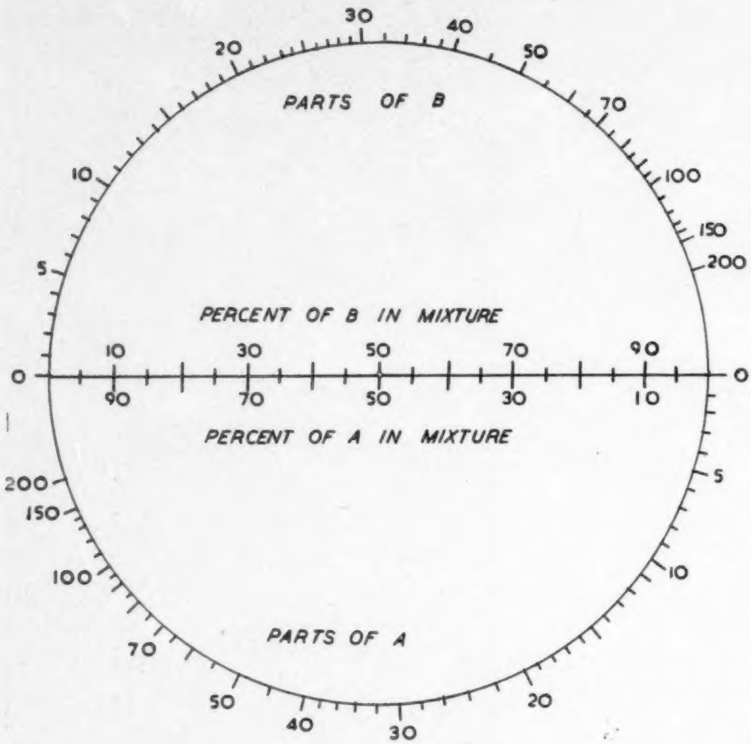
Each element consists of two stainless-steel U-channels into which $\frac{1}{8}$-in.-thick, roughly square 'biscuits' of enriched uranium, natural uranium and graphite are stacked in numbers and patterns which can be selected to correspond to practically any fuel dilution.

Only the central portion of each element is occupied by this mixture, the remainder of the stack consisting of thicker blocks of natural uranium.

A small gap is left between the two channels when they are clamped together so that the fuel element make-up can be checked at a glance. The reactor is brought into operation by raising eight fuel elements, so that their central enriched portion enters the core. They are suspended by steel cables from winding drums.

Composition of Mixtures

By G. E. Mapstone, M.Sc., Ph.D., F.R.I.C.



It is usually required that the composition of mixtures be quoted as a percentage. Now, if a parts of a material A are blended with b parts of material B, then the percentage of A in the mixture is

$$\frac{100a}{a+b}\% \quad \text{and the percentage of } B \text{ is} \quad \frac{100b}{a+b}\%$$

Although this calculation is quite simple, it has been our experience that the accompanying nomographic relationship has proved most convenient for routine use.

If mixtures of three or more components are made they can be handled readily by treating all except each individual component in turn as the second component, *e.g.* in a mixture of components C, D and E, treat C as A and $D + E$ as B, then D as A and $C + E$ as B, etc.

Organic power plant

Preliminary design of an organic-moderated and -cooled reactor for a 150-MW nuclear power plant will be conducted by Atomics International, a division of North American Aviation Inc., for the Baden Wurttemberg Nuclear Power Plant Planning Association (K.B.W.P.), of Germany, according to a recent agreement. The Brown Boveri Co. of Mannheim will perform overall planning for the project and conduct preliminary design of the conventional mechanical and electrical portion of the plant.

The work is expected to take about 13 months and would provide the basis for subsequent final engineering and construction of the power plant if K.B.W.P. should decide to proceed with construction.

CPE DIARY

MAY 29 TO JUNE 9 Practical course in **radiation safety and health physics** to be held at the City of Liverpool College of Technology. Details from J. W. Lucas, College of Technology, Byrom Street, Liverpool 3.

MAY 30 Symposium on **biochemical engineering** at the Royal Commonwealth Society, Northumberland Avenue, London, W.C.2. Details from the Institution of Chemical Engineers, 16B Belgrave Square, London, S.W.1.

JUNE 4 TO 8 National meeting of the **American Nuclear Society** to be held in Pittsburgh. Details from O. du Temple, American Nuclear Society, 86 East Randolph Street, Chicago, Illinois, U.S.A.

JUNE 9 TO 17 **13th ACHEMA exhibition congress** and **30th** meeting of the **European Federation of Chemical Engineering** to be held in Frankfurt-am-Main.

JUNE 8 **Reception and Conversazione of the Chemical Society,** to be held in the Science Museum, South Kensington, at 6.30 p.m. Details from the Chemical Society, Burlington House, London, W.1.

JUNE 19 TO 22 **Laboratory Apparatus and Materials** Exhibition to be held in the Royal Horticultural Society's New Hall, Westminster, London. Sponsored by *Laboratory Practice*. Details from the organisers, U.T.P. Exhibitions Ltd., 9 Gough Square, Fleet Street, London, E.C.4.

JUNE 19 TO 23 International **Instrument Show** to be held on the premises of the sponsors, B. & K. Laboratories, in Park Lane, London.

JUNE 19 TO 23 Annual conference of the Institute of **Sewage Purification** to be held at Brighton. This conference marks the 60th anniversary of the founding of the Institute. Details from the Institute, Maple Lodge, Mapel Cross, Rickmansworth.

JUNE 27 TO 30 British conference to consider **social and economic aspects of automation,** to be held in Harrogate. Details from British Institute of Management, 80 Fetter Lane, London, E.C.4.

What's New

in Plant • Equipment • Materials • Processes

CPE reference numbers are appended to all items appearing in these pages to make it easy for readers to obtain quickly, and free of charge, full details of any equipment, machinery, materials, processes, etc., in which they are interested. Simply fill in the top postcard attached, giving the appropriate reference number(s), and post it.

Large-bore pressure piping

The *Epoch* pipe system has been developed for large-bore, corrosion-resistant pressure piping by Bristol Aeroplane Plastics Ltd. The pipes and fittings are virtually unaffected by soils, sea-water, demineralised water and the majority of dilute acids and alkalis up to temperatures of 140°C.

The pipes are claimed to be as strong as steel and about ten times more flexible than the equivalent steel pressure pipes and thus suitable for laying over rough or uneven ground or in locations where soil subsidence is liable to occur.

The system comprises pipes and fittings 6 to 15¼ in. nominal bore, made from thermosetting epoxide resin reinforced with high-strength glass fibres. The standard 20-ft. pipes can be supplied bonded together to make 40-ft. or 60-ft. lengths if required. Fittings include both the standard tee section, with a branch at 90°, and standard bends catering for radii of 22½°, 45°, 67½° and 90°.

The system is divided into two series. Series A covers pressure piping systems operating at 100 p.s.i. and over and Series B operates below this. **CPE 1652**

Liquid oxygen evaporator

A new vacuum-insulated evaporator for liquid oxygen, nitrogen or argon was shown on British Oxygen's stand at the Engineering, Marine, Welding and Nuclear Energy Exhibition. It is designed for the small and medium consumer. Consisting of a vacuum-insulated vessel, a vaporiser and a control cabinet, the unit is about 10 ft. high, has a 30,000-cu.ft. capacity, and automatically vaporises and supplies oxygen at a predetermined pipeline pressure. The unit on show has an air-heated vaporiser giving a maximum flow rate of 1,000 cu.ft./hr. and, when fitted with larger vaporisers, it can supply up to 5,000 cu.ft./hr.

Liquid oxygen is delivered into the evaporator in consumer's works by B.O.C. pump tanker at a pressure of up to 300 p.s.i.g. The vessel can be filled before it becomes completely empty without disturbing the working pressure of the customer's pipeline. **CPE 1653**

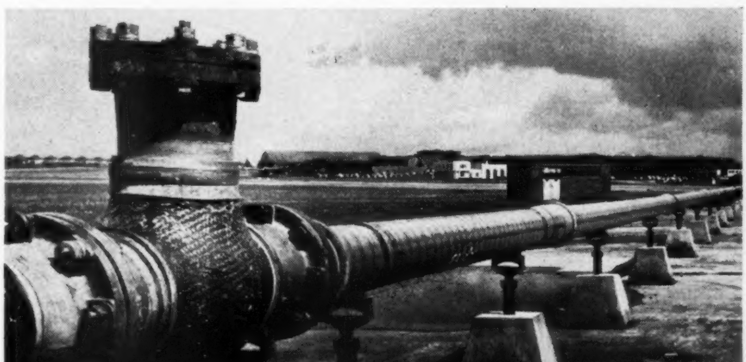
Industrial flowmeters

Rotron Controls Ltd. has recently been formed as a joint subsidiary of Elliott-Automation Ltd. and Rotron Controls Corporation of America to manufacture and market a range of industrial flowmeters together with auxiliary equipment to provide the oil, gas, petrochemical and water industries with a means of measuring positive and mass flow in pipelines.

The flowmeter operates on the principle of measuring the velocity of a fluid vortex created within the meter.

The *Vortex-Velocity* flowmeter consists essentially of a section of tubing having a pocket welded on one side. This pocket constitutes a chamber in which a vortex is generated by the fluid passing through the pipe. A wheel or rotor is mounted in this chamber having its axis at right-angles with the direction of flow of the product and revolving in unison with the vortex. There being a fixed and linear relationship between the speed of rotation of the vortex and the rate of flow of the product in the pipe, it follows that the revolutions of the rotor determine the volumetric flow.

The flowmeters are made in pipe sizes from 6 to 30 in. and capable of metering flows over 30,000 bbl./hr. **CPE 1654**

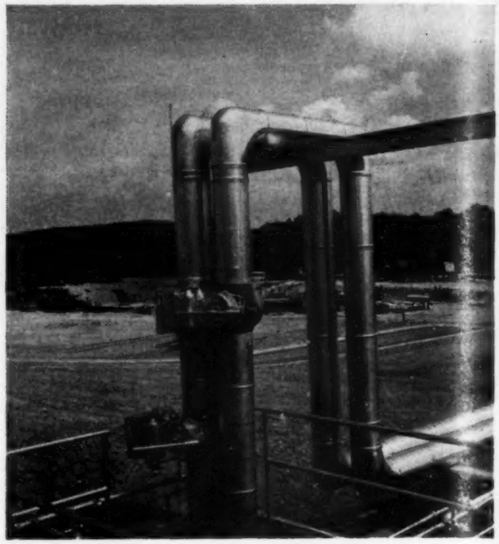


An installation comprising 20-ft. lengths of 6-in.-bore ' Epoch ' pipe with bonded joints. A standard flange-jointed tee is shown in the foreground

Calcium silicate insulation

Johns-Manville International Corp. offer a calcium silicate high-temperature block and pipe insulation recommended for use in power generation and process industries on both indoor and outdoor piping and equipment operating at temperatures up to 1,200°F. Repeated wettings are said to have no permanent effect on *Thermobestos*. Its lightness allows easy handling and fast application and its structural strength resists breakage. It will not burn or carry flame. It can be used in the presence of inflammable gases and liquids because it does not burn or propagate flames.

Another form of insulation, made by the same company, is *Metal-On* pipe insulation, which consists of *Thermobestos* prejacketed with high-quality aluminium. Supplied as an integral package, including a built-in vapour barrier, a section of this insulation snaps on to a pipe and locks tightly into place. **CPE 1655**



'Metal-On' pipe insulation

Fractionator

A fractionator has been developed for the separation of mixtures of high-boiling and heat-sensitive substances. In conventional columns such substances are exposed to the harmful effect of high temperatures at pressures above 20 mm. abs.

The new apparatus permits the sharp separation of multi-component mixtures at pressures of about 1 mm. abs. and with minimum pressure drop, a large number of equivalent theoretical plates, high throughput and the shortest hold-up time. The principle depends on alternate evaporation and condensation in a thin film and the device operates continuously as a stripping or fractionating column or in combination. A thin layer evaporator is used as reboiler.

The equipment is supplied in the U.K. by Luwa (U.K.) Ltd.

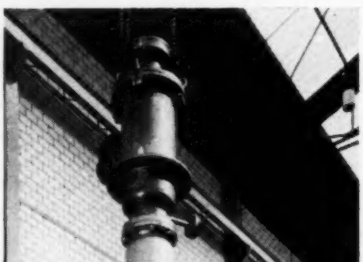
CPE 1656

Mineral wool insulation

Stilag preformed semi-rigid mineral wool pipe insulating sections, designed for insulating any type of pipe, in a range of temperatures from –400° to 1,500°F., is made by Stillite Products Ltd.

The sections are supplied in relatively short lengths, which facilitate handling on site, thereby reducing the risk of damage. The more frequent incidence of joints resulting from these shorter sections is claimed to be no disadvantage, since the inherent resilience of the material allows for butt joints.

A variety of finishes is available, the most popular being asbestos millboard cladding, which is resistant to damage and to fire. The surface can be painted as desired. **CPE 1657**



Fractionator for the separation of mixtures of high-boiling and heat-sensitive substances

Compressor

Atlas Copco (G.B.) Ltd. exhibited a new compressor at the Engineering, Marine, Welding and Nuclear Energy Exhibition. It is a short-stroke, double-acting stationary machine.

Its designers were set the task of planning a heavy-duty machine which could be transported in narrow mine shafts and drifts and sited close to headings. It had to be compact, to operate economically, have a long working life and yet be comparatively inexpensive.

To achieve these aims it was made with an unusually short piston stroke—equivalent to 21% of the diameter of the low-pressure cylinder. This meant that the piston speed could be kept down to 10.6 ft./sec. (3.23 m./sec.) at 970 r.p.m. At this speed the DT4 delivers 565 cu.ft./min. (16 cu.m./min.) at a normal working pressure of 100 p.s.i. (7 kg./sq.cm.).

CPE 1658

Switching unit

An electro-mechanical switching unit designed to provide electrical circuit switching from the rotation of a shaft by means of cam-operated heavy-duty switches is offered by Lancashire Dynamo Electronic Products.

The housing is splash-proof and is of cast light-alloy construction. Mounting is either by foot or by flange, both being integral parts of the housing. The switch is driven by a $\frac{3}{8}$-in.-diam. input shaft which is supported in a sealed bearing at each end of the assembly. Two sets of heavy-duty leaf-spring contacts are included and

the operation is determined by the form of the cam.

The rotary switch is primarily intended for use with the series F43 high-speed electromagnetic counter unit, but with an alternative cam-form the unit is said to be suited to limit switching on rotary valve actuators and similar applications. **CPE 1659**

Welding hard PVC galvanising drum with Welwyn Tool Co. welding torch

Increasing bulk density

Universal Processes & Plant Ltd. offer the *Vacupress* plant, a process intended for increasing the bulk density of powders. The principle is one of continuous de-aeration, by passing a stream of powder across a slowly rotating filter drum which is under vacuum internally.

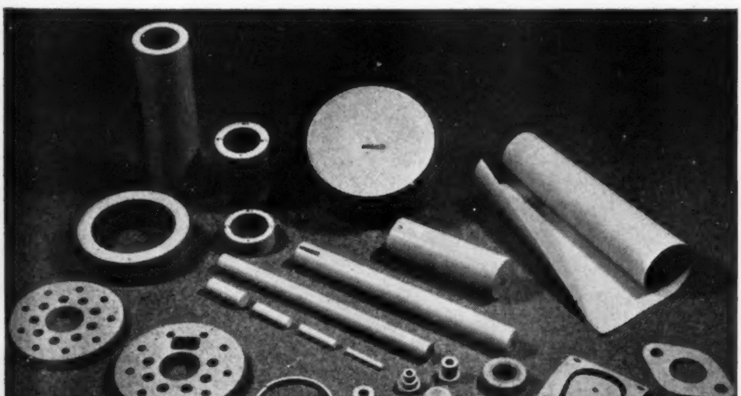
Materials for which this is recommended are carbon blacks, silicates, magnesium oxides and carbonates, lime hydrate, china clay, pigments and dyestuffs, and the manufacturers say that the applications are being extended to the pharmaceutical and general chemical fields.

Four standard sizes are available with capacities ranging from up to a few hundred lb./hr. to several tons/hr. **CPE 1660**

Small components

Large quantity production of small, filled PTFE-base-resin electrical and chemical component parts can be economically produced to close tolerances by techniques similar to those employed in the field of powder metallurgy. New equipment has recently been installed by Polypenco Ltd. at their Welwyn Garden City factory for mass production by this method. The present size range of pressed parts is limited to $\frac{3}{4}$ sq. in. cross-sectional area by $\frac{1}{2}$ in. maximum length, but this will be increased by the addition of further equipment.

Due to this installation the company has reduced the price of their *Fluorosint* shapes. **CPE 1661**



A selection of shapes, pressed parts and machine parts in 'Fluorosint'

Welding torch

The welding of thermoplastic materials has become a highly developed technique. A range of welding torches and auxiliary tools is offered for this purpose by the Welwyn Tool Co. Ltd.

The basic instrument is an electric hot air/gas plastic welding pistol. The temperature can be varied by the use of a two-step switch, two nozzles of different diameter and finally by adjusting the brass screw at the air intake.

The tool is automatically switched off by a thermostat. All metal parts are made of non-scaling stainless steel. The tool weighs 1 lb.

The torch can be used either with nitrogen gas or with hot air. The use of nitrogen is recommended for the welding of hard polyethylene and polypropylene. **CPE 1662**

Spherical powders

A process for producing spherical powders of metals and metal alloys with particles ranging in size from 20 to 150 microns with a uniformity rate of 98% has been developed by Union Carbide Corporation.

Produced in an inert atmosphere, the particles are said to be free of such defects as voids, cavities and inclusions. Powders available are copper, aluminium, nickel, 316 SS, tungsten and *Nichrome*.

These powders are recommended for applications, in the main, which can take advantage of their uniform spherical shape. For instance, they may be used to fabricate sintered bodies requiring controlled porosity. **CPE 1663**

New Books

Crystallisation. By J. W. Mullin. Butterworths Publications, London, 1961. Pp. 268, illus. 60s. net.

In spite of its great importance in industry, very little information has been published on what may be termed the practical side of crystallisation—considerable knowledge and experience being retained by comparatively few people inside the industries. Certainly no publication in the English language has previously appeared which has been devoted to the survey of all aspects of crystallisation practice. The publication of Prof. Mullin's work remedies the omission.

Much material has already been published on the specialised subject of crystalline state and crystallography and in his first chapter the author rightly confines himself to a brief introduction on the subject. The short bibliography for recommended study is adequate.

Chapters 2, 3 and 4 deal with solutions and solubility, the fundamental physical and thermal data on which crystallisation depends, and phase equilibria. Explanations are clear and precise and useful information is given. However, these subjects are of prime importance to the designer and reference to *I.C.T.*,[1] Kirk-Othmer[2] and that most comprehensive of all works on solubility—Seidell[3]—may well have been made. In industrial practice pure solutions are the exception rather than the rule and it is felt that greater emphasis should have been made on this point.

The effect of impurities, existent or added, of surface-active agents, of *p*H, of viscosity and temperature upon the growth rate and habit of the crystal can be most pronounced. The aspect of crystal growth giving rise to hard scale formation which is often most troublesome and one of the nightmares of the crystalliser designer and operator is important. More information on this subject in chapter 5 on the 'Mechanism of Crystallisation' could have been usefully added, albeit in a general way. The complexity of the variables involved in the crystallisation process makes anything but broad comment impossible and is probably the major reason for the scarcity of published data on practical applied crystallisation and for such data as are published being related to a specific substance being crystallised.

Crystallisation as practised in industry and the type of crystallisation equipment employed are amply dealt with in Chapters 7 and 8.

Prof. Mullin concludes with Chapter 9 on the subject of size grading of crystals and gives emphasis to the importance of uniform particle size as the criterion of good crystalliser design. In industrial practice, crystallisation does not end with making of crystals in the crystalliser. The crystals must first be separated from their mother liquors and frequently dried and stored. Too frequently uniform and attractive coarse crystals produced by a crystalliser are broken and spoilt, soft friable crystals are disintegrated, and small crystals cannot be separated from the liquors because the wrong type of dewatering equipment, drier or conveyor has been used. Whilst dewatering, drying, conveyance and storage are separate unit processes they are so closely allied to that of crystallisation that some reference should have been made generally on these subjects.

Useful tables on solubility and heats of solutions are given in the appendix.

Criticism can only be of omissions. Within the space available, Prof. Mullin has successfully achieved his aim of presenting crystallisation as a unit operation. Whilst crystallisation, because of the very complexity of the subject, must remain very much an art, the author has shown where science emerges. The book is not only concise, but is presented in an easily readable manner which should make it doubly attractive and of value not only to students of chemical engineering but to the process chemist and chemical engineer.

REFERENCES

[1] 'International Critical Tables'. McGraw-Hill Book Co. Inc., London, 1933.

[2] 'Encyclopaedia of Chemical Technology' (ed., E. R. Kirk and D. F. Othmer). The Interscience Encyclopaedia Inc., New York, 1954.

[3] Atherton Seidell: 'Solubilities of Inorganic and Metal Organic Compounds', Third Ed., Vol. I, D. van Nostrand Co. Inc., New York, 1940; 'Solubilities of Organic Compounds', Third Ed., Vol. II, D. van Nostrand Co. Inc., New York, 1941. Atherton Seidell and William F. Linke: 'Solubilities of Inorganic and Organic Compounds', Suppl. to Third Ed., D. van Nostrand Co. Inc., New York, 1952.

A. W. BAMFORTH

Applied Chemistry for Engineers. By E. S. Gyngell. Edward Arnold (Publishers) Ltd. 28s. net.

'This edition has been completely revised and reset . . .' according to the notice on the dust cover, and this is implied in the author's preface.

More than half this book is devoted to fuels and combustion processes, and it is within this section that an account appears on nuclear power and nuclear fuels which is quite adequate for the general reader. The chemistry and palaeobotany of solid fuels are essentially studies for the fuel technologist, but it is very doubtful if the average industrial engineer requires more than a broad, general conception of the properties of these fuels. If, in this book, this portion had been epitomised, more space could, perhaps, have been devoted to the later divisions dealing with the important fields of materials of construction.

Where carbonisation of coal is described, it is quite superfluous to describe the operation of beehive ovens which have long been obsolete. Modern ovens receive a charge of some 14 tons (not 22 tons) and the carbonisation time is some 7 hr. with a wall temperature of 1,000° to 1,100°C. (not 24 hr.). Dry cooling is not now practised, at any rate in this country. Soda ash is not used as a neutralising agent in the manufacture of sulphate of ammonia, and it would lead to great simplification if the removal of hydrogen sulphide from impure gases were as elementary as the account implies. Electrostatic precipitation is now invariably used for the removal of tar fog from crude coal gas. In oil-washing of this gas, ring packings are not used for reasons which are obvious to the technologist engaged in this industry.

Producer gas processes are very widely used in industry, for example in the glass industry, together with blast-furnace gas which is similar in properties. The mechanism of production and properties of these gases is suitably presented, but the physical chemistry discussion on heat of reaction could very well be extended and clarified somewhat.

An elementary account of liquid fuels is presented, including petroleum, coal tar and selected synthetics. The pot still, for coal-tar distillation, is used only on small, obscure, plants and is quite outmoded. The same remarks apply to the benzole rectification plant shown as a pictorial flowsheet.

Combustion calculations performed

by the methods shown are laborious. Molal units are much more satisfactory, more comprehensive and easy to transform in stoichiometric computations. The chemical engineer invariably uses this system and it is now common in the training of engineers in other technologies.

It is appropriate to discuss materials of construction and protective methods against corrosion in a book of this nature, but these topics must be considered at length. The material given is commonly to be found in most texts on chemistry. The industrially important alloys are ignored. Pure lead is rarely used, even on a small scale, and the important phenomenon of 'anhydrous attack' on aluminium is not mentioned. The growing industry manufacturing titanium white requires much more detailed discussion than the mere mention given to it in the section on paints.

The mechanism of water treatment is adequately described, but no discussion is given on the interpretation of the results of chemical tests and analyses of waters. The practising engineer needs to be able to read into analytical reports the practical implications of plant operation.

The book concludes with chapters on effluent disposal and cements. One might have expected a description and an account of the uses of refractories at this section.

It is probable that this text is intended for use as a class textbook, which would be amplified in a lecture course. It is of little direct use to the practising engineer.

H. K. Suttle

Molecular Distillation. By G. Burrows. Clarendon Press: Oxford University Press, 1960. Pp. 214. 35s. net.

This book is a useful attempt to present the theory and practice of molecular distillation in a co-ordinated and comprehensive manner. The book is well referenced and the chapters dealing with vacuum technique, mechanical design, types of apparatus, operation and control and utilisation of the process are valuable practical sections.

The author describes evaporative distillation, rate of vaporisation, rate of evaporation, distillation by boiling, normal evaporative distillation, molecular evaporative distillation, batch molecular distillation, equilibria distillation, etc. All these operations are concerned with the transport of molecules and the text would have benefited by a discussion of the mass-transfer mechanisms involved. In this discussion the difference between the Higbie 1.4 and kinetic equations 2.6 and 2.13 in relationship to the above evaporation and distillation processes could usefully have been expanded.

Equation 3.5 defines the activity coefficient as a correction factor to Raoult's law for non-ideal systems where there is a change in volume on mixing in the liquid phase. In equations 3.18, 3.19, 3.20*a* and 3.20*b* the activity coefficient (using the same nomenclature) is used to define not only solution effects, but also collision effects, persistence-ratio effects, mean free path, distance between the condensing and heating surface, etc. It is doubtful if this latter use of the word activity coefficient is justified as the term has a well-defined thermodynamic basis in the theory of solutions in distillation.

This book would also be improved by the inclusion of a list of nomenclature as is common practice in chemical engineering books.

S. R. M. Ellis

Management of Nuclear Materials. Ed. Ralph F. Lumb. D. Van Nostrand Co. Inc., 1960. Pp. 516. £6 4s.

When an entire industry is founded as a result of some spectacular scientific development it tends to reflect a continuous aura of scientific glamour; many bright and capable scientists and engineers are then prepared to work in this industry fully believing that they too will one day aid in some further scientific discoveries. What is often forgotten, however, is that much routine and commonplace work must be carried out in any new industry in order to make it run efficiently and economically.

Such is the case of the nuclear industry which attracted all the finest technical brains after the war years but often had to employ them in routine tasks similar to those occurring in every other industry: how to control stock and how to convert laboratory and pilot-plant results into large-scale processes that can be operated satisfactorily and safely by a minimum number of men. A book on the management of nuclear materials (which is defined in the introduction as 'recording, evaluation and presenting quantity data necessary for the control of nuclear material') will, therefore, form a valuable addition to the many other books on nuclear technology.

The book, in the form of a compendium edited by Ralph F. Lumb, who is director of the Western New York Nuclear Research Centre, is divided into seven parts which are further sub-divided into chapters.

The seven parts of this book are entitled as follows: basic management considerations, raw materials, materials processing, reactor fuel fabrication, reactor operation, recovery and research, and development facilities. The first part is probably the weakest section of the book, dealing with the philosophical implications behind nuclear materials management—it is always unfortunate when management generalities of a 'common-sense' nature are presented in a technical book; the reader is likely to regard this as mere padding and to judge the merit of the technical section in the same light.

The other sections describe in great detail the various processes at present carried out in the American nuclear industry, at the same time mentioning how nuclear materials are controlled and accounted for throughout every process. Unfortunately, often American processes do not correspond to British and French processes. On page 183, for example, it is claimed that only three basic materials have been widely employed for cladding nuclear fuel elements: aluminium, stainless steel and zirconium. *Magnox* has not been included—this would seem strange to anyone familiar with British reactors!

A most surprising omission is the fluidisation process for denitration of uranyl nitrate hexahydrate to uranium trioxide followed by reduction to uranium dioxide and subsequent conversion to uranium tetrafluoride.

Despite this American 'bias' (which is really quite excusable in view of the difficulty in obtaining details of process operations from other countries), the authors have written succinctly and logically in a very difficult field. Diagrams illustrating the texts are remarkably good as is the general presentation. The price of the book at £6 4s. is somewhat excessive and this might tend to restrict its circulation to libraries and large companies.

I.L.H.

Personal Paragraphs

★ **Mr. Richard Melville** has been appointed Scientific Attaché to the British Embassy in Paris. He has been in the Department of Industrial and Scientific Research since joining the Geological Survey and Museum in 1938. He has recently been on secondment to the International Commission on Zoological Nomenclature as assistant secretary, which has brought him into close contact with French scientists.

★ **Mr. D. J. Flunder,** general purchasing manager of the Dunlop Group for the past two years, is to become general manager of the chemical products division in Birmingham. He will succeed **Mr. N. G. Bassett Smith,** who is to become general manager of the Dunlop Footwear Co. at Walton, Liverpool.

★ **Mr. D. A. Brighton** has been appointed an assistant technical service manager of Vinyl Products Ltd. He joined the technical service department of the company in 1953. He was previously in charge of the textile and paper sections of the technical service laboratory.

★ **Mr. A. B. Miles** has been appointed chief engineer of Darchem Engineering Ltd. He has been six years with the company. He is succeeded as chief draughtsman by **Mr. F. Meadows,** at present assistant chief draughtsman. **Mr. D. A. Rowlett** has been appointed manager of the Rosetenit division of the company.

★ **Mr. John Marsh** has accepted an invitation to become director of the British Institute of Management from October 1, 1961. Since 1950 he has been director of the Industrial Welfare Society.

★ **Prof. Dr. J. A. Goedkoop,** head of the physics department of Reactor Centrum Nederland, has been appointed managing director of research. He has been associated with the centre since its foundation in 1955. He is part-time professor at the Leyden State University.

★ Following the acceptance of holders of more than 90% of the shares of W. J. Bush & Co. Ltd. of Albright & Wilson's offer to acquire the share capital of that company, **Mr. E. L. Bush,** chairman of W. J. Bush & Co. Ltd., was appointed a director of Albright & Wilson Ltd.

★ **Mr. T. J. Woodthorpe** has been appointed to the board of Cyanamid of G.B. Ltd. He is a biochemist in charge of the company's pharmaceutical and general chemical installations at Gosport, Hampshire.

★ **Mr. Derrick H. Carter** has been appointed chairman of I.C.I. Ltd. General Chemicals Division in succession to Mr. Harold Smith, who was recently appointed to the I.C.I. main board. Mr. Carter is succeeded as joint managing director (commercial) of General Chemicals Division by **Mr. John L. Tedbury,** a director of the Division.

★ **Mr. A. C. Crockett** has been appointed to the board of directors of the Brooke Tool Manufacturing Co. Ltd. He has been with the company some 20 years and was appointed works manager two years ago. He is a member of several technical committees of the British Standards Institution and also serves on the Technical Committee of International Standards Organisation on engineers' small tools.

★ Two former directors of I.C.I. Lime Division, **Mr. F. C. Covil** and **Mr. C. S. Hall,** retired recently from the company. When the Lime Division was absorbed into I.C.I. alkali division last year, both became local directors at Buxton, the former headquarters of the lime division. Mr. Covil has been some 35 and Mr. Hall 34 years with I.C.I. and its predecessors. Both first joined Synthetic Ammonia & Nitrates Ltd. at Billingham.

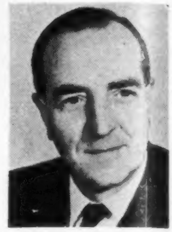
★ At the inauguration of the Scottish Branch of the Institution of Chemical Engineers **Mr. T. Flavel** was elected chairman, **Prof. A. W. Scott** vice-chairman and **Dr. D. M. Wilson** secretary.

★ The death occurred recently of **Mr. R. B. Kerr,** M.B.E., deputy managing director of Foster Wheeler Ltd. He joined the company in 1949 as an engineer in the process plants division.

★ **Sir John Carmichael,** K.B.E., has been appointed to the board of Fisons Ltd. He was Under-Secretary to the Sudan Ministry of Finance and Economics from 1954 when the state became self-governing. From 1956 to 1959 he was Financial and Economic Adviser to the Sudan Government. He was a member of the U.K. Delegation to the General Assembly of the United Nations in 1959. In March 1960 he was appointed chairman of Fisons Pest Control's Sudan subsidiary company and later in that year he became a director of Fisons Pest Control Ltd. in the U.K.

Mr. T. J. Woodthorpe

Mr. D. H. Carter



Mr. J. L. Tedbury

★ Due to the resignation of **Mr. William Reid** from executive duties in the Distillers Co. Ltd., the following appointments have been made. **Mr. T. F. A. Board** has become chairman of the management committee. **Mr. H. H. Woolveridge** has been appointed as a member of the management committee. **Mr. P. H. Hogg** has been appointed chairman of John Haig & Co. Ltd., **Mr. W. D. Burnet** chairman of Scottish Malt Distillers Ltd.

Leonard Hill Trophy

The spring meeting of the Golfing Society of the Institute of Incorporated Practitioners in Advertising was held on March 28 and was attended by a record number of players. The Leonard Hill Trophy for agencies competing was won by Mr. D. Taylor and Mr. W. E. Osborne of Osborne-Peacock. The Strong Challenge Trophy was won by Mr. A. Scott of Foster, Turner & Benson. The Leonard Hill Trophy, which is awarded by Mr. W. Leonard Hill, chairman of the proprietors of this journal, was presented to the winners by Mr. R. Nash, captain of the club.

CPE Company News

Silicone plant expansion

New plant worth more than £500,000 came into operation during April at the Midland Silicones Ltd. factory at Barry, South Wales.

The new installations include a plant for manufacturing methyl chloride, one of the prime raw materials for silicone production; a new direct-process unit for the production of chlorosilanes, which will nearly double the previously existing capacity; and a new silicone fluids production unit with more than twice the capacity of the equipment at present in use.

The continuing capital construction programme will provide the following facilities:

(1) New plant to manufacture emulsions for use as release agents and for the treatment of textiles and paper. This plant is to be brought into operation this year.

(2) A further direct-process reactor, to be completed in 1962.

(3) Additional distillation columns, to come into service in 1962.

(4) New production equipment for the manufacture of various siloxane intermediates. This unit will have a capacity more than three times that at present available and is to be in operation in 1962.

British company in American Institute

Head Wrightson Processes Ltd. has been elected to membership of the Cooling Tower Institute. This is the only British manufacturer to be accepted by the Institute, which was formed in America over 10 years ago to advance the technology, design and performance of industrial water-cooling equipment, and to conserve water as a natural resource.

In association with the Fluor Products Co., of California, U.S.A., Head Wrightson have for many years been concerned in a programme of research and development into improved methods of cooling and recently introduced a new range of cooling towers for small industrial duties. The cooling, heating and treatment of water forms the basis of a comprehensive service available to all process plant operators.

L.P.G. tanker

One of the most important shipyards in Japan, Mitsubishi Nippon Heavy Industries (Yokohama) Ltd., is building a refrigerated L.P.G. tanker for the Bridgestone Liquefied Petroleum Gas Co. Ltd., of Tokyo. The vessel will have a capacity of 180,000 bbl., equivalent to about 17,000 tons of refrigerated L.P.G. at about -40°F., and a service speed of 16 knots.

This ship has been designed by Conch International Methane Ltd. for the owners. The world's first liquid methane carrier, the *Methane Pioneer*, was designed and developed by the same company and the Bridgestone tanker will incorporate much of the know-how and experience gained on this vessel.

The tanker will be the first large-scale commercial ship to carry L.P.G. at essentially atmospheric pressure and is scheduled for completion early next year. Supplies of refrigerated L.P.G. are being obtained from Kuwait and, in Japan, the L.P.G. will be distributed by Bridgestone for industrial and domestic use (as bottled gas).

Fertilisers in Belgium

Fisons Fertilizers Ltd. have formed a new fertiliser manufacturing company in association with Union Chimique Belge of Brussels. Known as Fison U.C.B. S.A., the company will produce high-analysis granular compound fertilisers for the Belgian domestic market and for neighbouring Common Market countries. A manufacturing plant is to be built at Zandvoorde, near Ostend, and production is planned to start in the summer of 1962.

The plant will initially be capable of a production rate of 20 tons/hr.

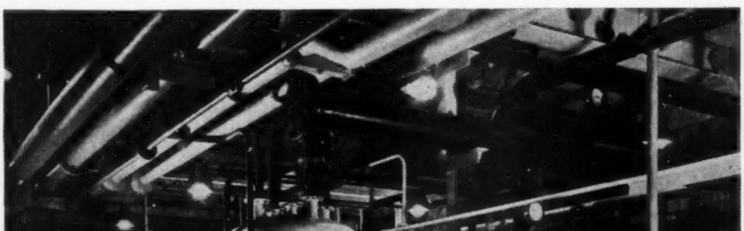
Fison U.C.B.'s factory site at Zandvoorde will be within the present U.C.B. factory boundary and U.C.B. will supply the new company with nitrogenous material and phosphoric acid.

Nylon plant in Antrim

British Enkalon Ltd., subject to the acquisition of a suitable site, is to build a nylon factory at Antrim, Northern Ireland, to produce nylon yarn and raw material for the plastics industry.

The company is an Anglo-Dutch company to be jointly formed by British Enka Ltd. of Liverpool and Algemene Kunstizijde Unie of Arnhem in the Netherlands.

At present Courtaulds Ltd. are manufacturing viscose rayon at Carrickfergus, Co. Antrim, and Chemstrand Ltd. are producing *Acrilan* at Coleraine, Co. Londonderry. I.C.I. are building a large factory at Kilroot, Co. Antrim, for the production of *Terylene* and perhaps eventually polypropylene. The production of nylon will complete the company's full range of man-made fibres.



Devolatilisation equipment on the new silicone fluids plant at Midland Silicones

World News

ARGENTINA

Salicylic acid and phenol

Production of salicylic acid and phenol has commenced in the San Nicolas works of Fensud Fabrica Argentina de Fenol y Derivados S.A. of Buenos Aires. This is a joint company formed by Farbenfabriken Bayer A.G. of Leverkusen and the Argentinian branch of Bunge & Born-Konzern. The processes were developed by Bayer. The capacity should satisfy the Argentinian market's requirements for phenol and salicylic acid.

DENMARK

Oil refinery

The American company, Gulf Oil Corporation, is to erect an oil refinery near Stigsnaes in south Jutland, capable of refining up to 1.5 million tons p.a.

The refinery will in the first instance supply fuel oil and gasoline for the Scandinavian market. The crude oil will be shipped from Kuwait. Production is scheduled to commence at the beginning of 1963.

Another American company, Tidewater Oil Co., is already in the process of erecting a refinery near Kalundborg in north Jutland.

MEXICO

Plant manufacture

Kestner Evaporator & Engineering Co. Ltd. has licensed Dicon S.A. de C.V. of Mexico City to manufacture products including chemical evaporators, crystallisers, dryers, acid-proof equipment, etc.

A licence has also been granted by Richard M. Armstrong Co. of U.S.A. to Dicon to manufacture Armstrong heat-transfer equipment in Mexico. This includes shell and tube exchangers for chemical and petroleum plants, air-cooled heat exchangers, vaporisers and refrigeration shell and tube apparatus including scraped shell heat exchangers for petroleum refining.

A plant for the manufacture of these products is under construction in the Colonia Vallejo area of Mexico City.

IRAQ

Sulphur found

Iraqi and Soviet surveyors have found large deposits of sulphur in commercial quantities in northern Iraq. Mr. Jabir, a director of General Industrial Design & Construction, said that an experts' report will be ready within three months and the government would then know how many millions of tons of sulphur exist.

The Russians, who are working in Iraq under a March 1959 technical and economic co-operation agreement, have also found pure high-quality lead deposits in Mosul province, and silicon and phosphate deposits in Rutba, near the Syrian border.

FINLAND

Sodium sulphate plant

Construction of a sodium sulphate plant has been planned by Rikkehappo Ja Superfosfattitehtaat O.Y. of Helsinki. The plant will comprise 10 mechanised sulphate furnaces each of 6 m. diam., for the pretreatment and automatic charging of raw material. The capacity of the plant will be about 70,000 tons p.a. sodium sulphate.

AUSTRALIA

Queensland's refinery

The Queensland Government and American interests have signed an agreement that will give Queensland its first oil refinery. The refinery will be built by Amoco Pty. Ltd., the Australian subsidiary of the Standard Oil Co. of Indiana.

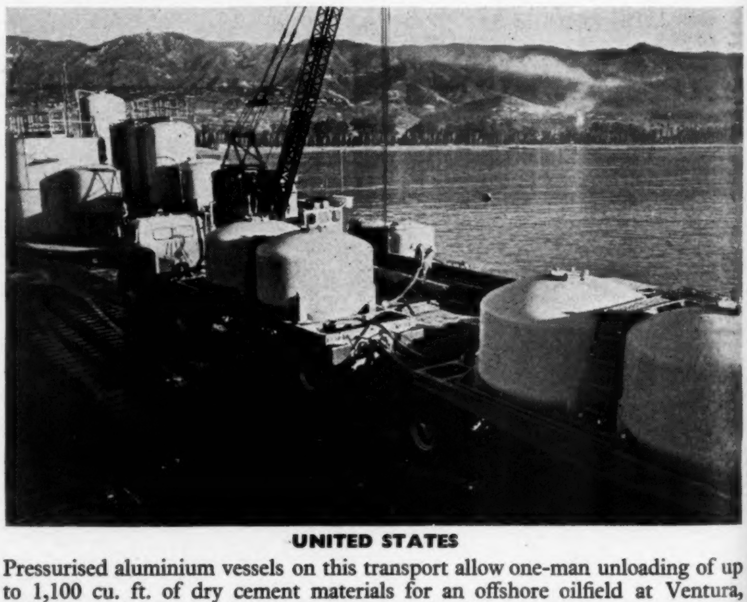
The agreement provides for the reclamation of a factory site near the mouth of the Brisbane River.

GERMANY

Phthalic anhydride plant

Harpener Bergban A.G., of Dortmund, have built a plant for the production of phthalic anhydride. The capacity is estimated at 7,500 tons p.a. and the plant will be on stream by the end of the year.

The raw material for this process is naphthalene, which is obtained in large quantities from coke ovens.



UNITED STATES

Pressurised aluminium vessels on this transport allow one-man unloading of up to 1,100 cu. ft. of dry cement materials for an offshore oilfield at Ventura, California. No mechanical conveyors are used. Dry materials are blown from the vessels at a pressure of 15 p.s.i. By hooking up a 4-in. hose the entire load is transferred to a dockside barge in about 20 min.

The transport was developed by B.J. Service Inc., of Long Beach, California. Made of Kaiser Aluminium alloy plate, the vessels each weigh 800 lb. and will carry up to 275 cu. ft. of dry material.

£ s d

CHEMICAL PLANT COSTS

Cost indices for the month of March 1961 are as follows:

Plant Construction Index: 183.3

Equipment Cost Index: 173.2

(June 1949 = 100)

£ s d